1997-1999 Priorities

AND PROGRESS UNDER THE

Great Lakes Water Quality Agreement

JANUARY 2000

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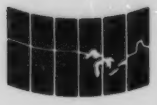

Report to the
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Joint Commission

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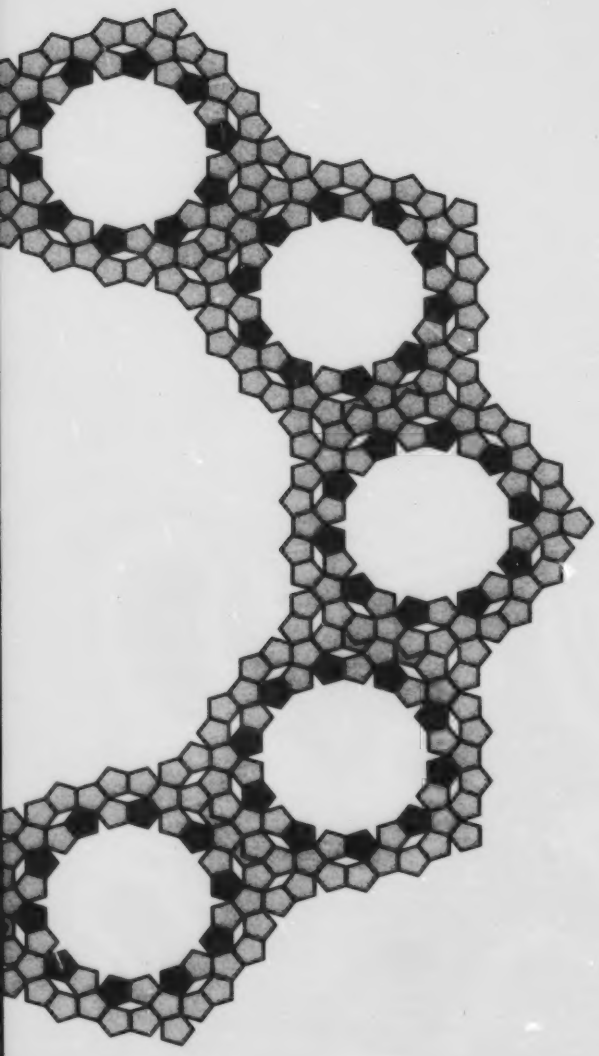

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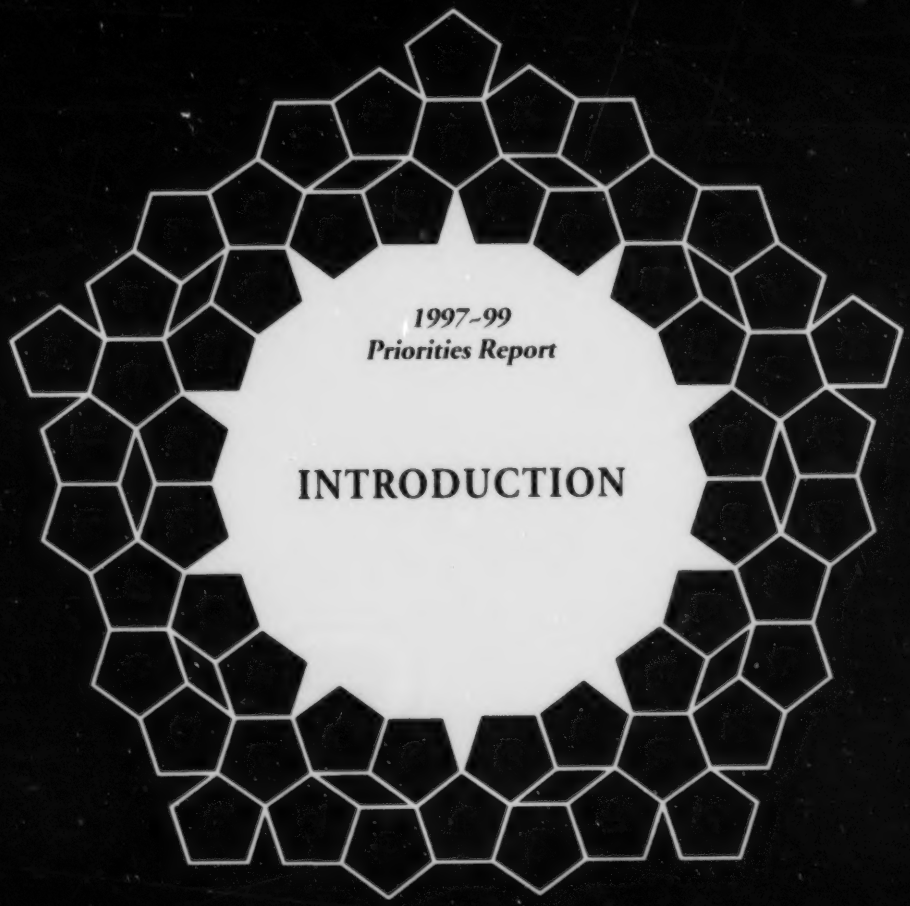

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INTRODUCTION

INTRODUCTION

In the **Great Lakes Water Quality Agreement**, the **United States and Canada** (the Parties) agree "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To achieve this purpose, the Parties have undertaken numerous programs, policies and other measures and have obligated themselves to periodic reporting on their progress.

The International Joint Commission's (IJC) role is to evaluate and assess the Parties' programs and provide a report at least every two years that presents its findings, advice and recommendations. To fulfill its evaluative role, the IJC relies upon numerous sources. A major source of information and assistance are the two joint institutions established under the Agreement – the **Great Lakes Water Quality Board** (WQB) and the **Great Lakes Science Advisory Board** (SAB).

As principal advisor to the IJC, the WQB comprises 20 program managers and administrators drawn from the two federal governments, the eight states and two provinces in the Great Lakes-St. Lawrence River basin. The SAB, whose 18 members represent a broad range of disciplines, provides scientific advice to both the IJC and WQB.

In 1984, the IJC established the Council of Great Lakes Research Managers whose 22 members provide advice related to the coordination and evaluation of Great Lakes research efforts. Given the significance of the air as a pathway by which contaminants reach the waters of the Great Lakes, the IJC relies on its International Air Quality Advisory Board (IAQAB), established in 1966 under the auspices of the Boundary Waters Treaty, to provide advice in this regard. The IJC also establishes task forces and other groups to address specific issues or subjects that are particularly germane to fulfilling the Agreement purpose.

Recognizing the need to secure the views and opinions of basin stakeholders, the IJC engages in a variety of public consultation activities. The information received from this broad-based consultation contributed significantly to the insight, advice and recommendations that The IJC provides to governments through its biennial reports.

To manage its human and financial resources, the IJC establishes priorities based on the advice it receives from its advisory boards. The priorities for the current 1997-99 cycle were drafted in fall 1997, presented publically for discussion at the November 1997 Biennial Forum held in Niagara Falls, Ontario and formally adopted by the IJC Commissioners later that month. The 1997-99 priorities are summarized in the following table. Responsibility to undertake the priorities was assigned to the WQB, SAB, IAQAB, the Council of Great Lakes Research Managers, the Indicators Implementation Task Force, and the Annex 2 Advisory Committee.

The six chapters in this report were prepared by the groups responsible for the identified priorities. They define and describe the specific investigations undertaken to support each priority and present the groups' findings, conclusions and recommendations. No attempt was made to harmonize the content or recommendations, as they represent each groups particular advice to the IJC with respect to their charge and obligations.

COMMISSION PRIORITIES FOR 1997-99

PRIORITY	**ANNEX 2: REMEDIAL ACTION PLANS AND LAKEWIDE MANAGEMENT PLANS**	
SUMMARY	To assist the Parties in the development and implementation of RAPs and LaMPs through: conducting status assessments to evaluate activities, workshops to transfer information and foster implementation, and RAP and LaMP reviews in order to gauge progress toward restoration of beneficial uses.	
RESPONSIBILITY	Lead:	Annex 2 Advisory Committee in collaboration with the Great Lakes Science Advisory Board and the Great Lakes Water Quality Board
PRODUCT (CHAPTER)	1.3	Meeting to Assess Scientific Issues in Lakewide Management Plans for Critical Pollutants
	1.5	AOC Site Visits: Cornwall and Massena, St. Mary's River and Grand Calumet
	2.3	Protecting What Has Been Gained in the Black River
	2.4	Rehabilitating and Conserving Detroit River Habitats
	3.1	AOC Status Assessments: Detroit River and St. Mary's River
	3.2	Human Health Considerations in LaMPs and RAPs
	3.3	Comparisons of Remedial Options in AOCs
	3.4	Public Consultation and Participation in AOCs
	5.3.6	RAP and LaMP Research Needs

PRIORITY	**INDICATORS**	
SUMMARY	To implement the advice provided by the Indicators for Evaluation Task Force in 1996	
RESPONSIBILITY	Lead:	Indicators Implementation Task Force with assistance from the Great Lakes Science Advisory Board
PRODUCT (CHAPTER)	4.1.1	Workshop on Indicators of Integrity and Diversity of the Great Lakes Basin Ecosystem
	4.2.3	SOLEC 1998: Breakout Session on Implementing Indicators
	4.4.4	Technical Review of SOLEC Draft Indicator Reports
	4.4.5	IAGLR 1999: Breakout Session on Swimmability, Fishability and Drinkability
	4.6	Desired Outcomes and Indicators
	5.3.2	Indicators Implementation

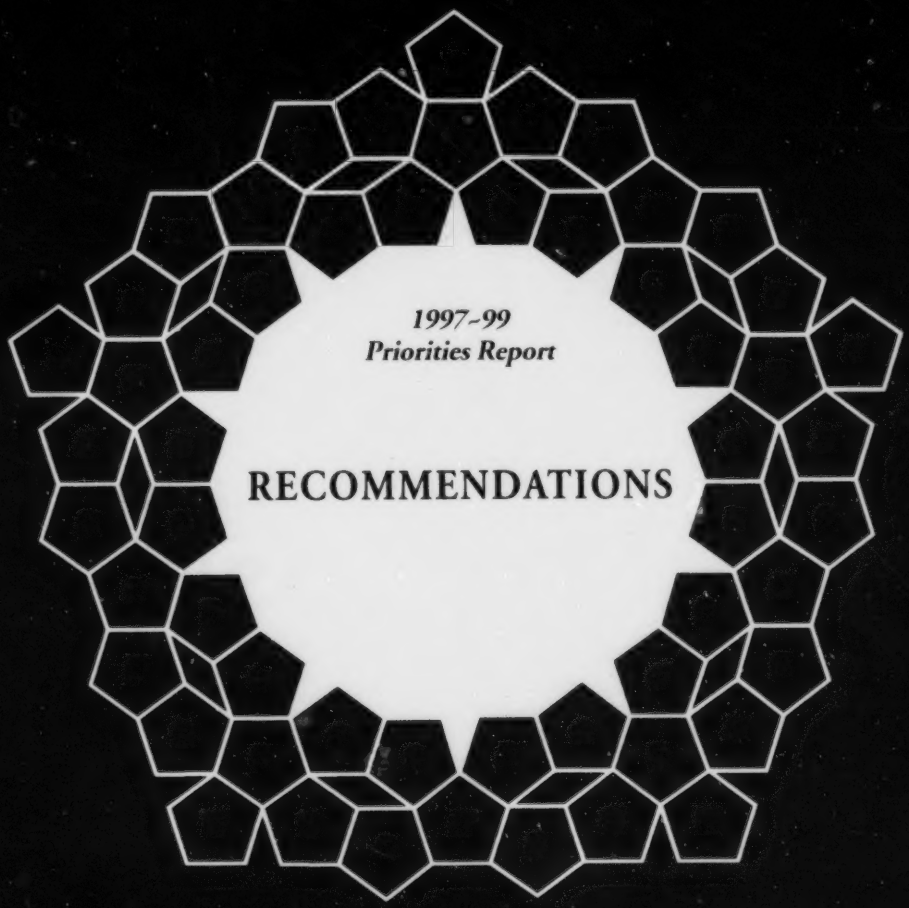
PRIORITY	**PERSISTENT TOXIC SUBSTANCES: REVIEW OF GOVERNMENT PROGRESS IN CONTROL AND MANAGEMENT**	
SUMMARY	To assess the Parties' efforts to further determine the impact of persistent toxic substance on the Great Lakes and to develop a control/prevention strategy.	
RESPONSIBILITY	Lead:	Great Lakes Science Advisory Board
PRODUCT (CHAPTER)	1.4.1	Water Quality Criteria Workshop

PRIORITY	REVIEW OF GOVERNMENT PROGRAMS AND CHANGING PROGRAM THRUSTS
SUMMARY	To review decreases in the Parties' resources and effects of these changes on the ability of the Parties and other jurisdictions to meet the commitments of the Great Lakes Water Quality Agreement.
RESPONSIBILITY	Lead: Great Lakes Water Quality Board
PRODUCT (CHAPTER)	2.2 Report summary

PRIORITY	CONTAMINATED SEDIMENT
SUMMARY	To compile and disseminate information on the economic and environmental benefits of sediment remediation and develop guidance for making decisions regarding management of contaminated sediments to assist in furthering efforts to remediate AOCs.
RESPONSIBILITY	Lead: Great Lakes Water Quality Board in collaboration with the Great Lakes Science Advisory Board and the Council of Great Lakes Research Managers
PRODUCT (CHAPTER)	2.6.1 Report summary: Data Interpretation Tools for Making Sediment Management Decisions Beyond Source Control 2.6.2 Report summary: Ecological Benefits of Sediment Remediation in the Great Lakes Basin 2.6.3 Report summary: Economic Benefits of Sediment Remediation

PRIORITY	REVIEW AND EVALUATION OF NON-POINT SOURCES
SUMMARY	To review government programs for controlling pollution from land-use activities.
RESPONSIBILITY	Lead: Great Lakes Science Advisory Board
PRODUCT (CHAPTER)	1.6 Meeting summary: Nonpoint Sources of Pollution to the Great Lakes Basin

OTHER PRIORITIES AND INITIATIVES	
SUMMARY	Identify and provide insight and advice on other topics relevant to fulfilling the purpose of the Great Lakes Water Quality Agreement and in accordance to the directive to the Great Lakes Water Quality Board, Great Lakes Science Advisory Board and the Council of Great Lakes Research Managers, including emerging issues.
PRODUCT	1.7 Watching brief on Endocrine Disruptors 1.8.1 Aboriginal People 1.8.2 Coupled Great Lakes Observation and Modeling System 1.8.3 Public Survey: Emerging Issues Identification 1.8.4 An Emerging Risk from Nitrogen 2.4 Rehabilitating and Conserving Detroit River Habitats, Conclusions and Recommendations 2.7 Addressing Concerns for Water Quality Impacts from Large-scale Great Lakes Aquaculture 5.2.1 Great Lakes Research Inventory 5.2.3 Great Lakes Communicators Network Formation 5.2.4 Organization Survey: Biodiversity and Habitat Goals in the Great Lakes



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RECOMMENDATIONS

RECOMMENDATIONS

The following 51 recommendations were developed by the Science Advisory Board, the Water Quality Board, Indicators Implementation Task Force, the Council of Great Lakes Research Managers, and the International Air Quality Advisory Board. Substantiating details are provided in the sections indicated.

SCIENCE ADVISORY BOARD RECOMMENDATIONS

Threat to Human Health — Page 6

1.3.1 The IJC advise the Parties to collaborate on the preparation of a comprehensive statement, for the entire Great Lakes basin, of the threat to human health posed by critical pollutants and that this comprehensive assessment be used in the preparation of Lakewide Management Plans.

1.3.1 The IJC urge the Parties to increase consultation between health authorities and local communities to assist them, and particularly vulnerable subpopulations, to discern whether adverse effects, either overt or subtle, are occurring due to their exposures to persistent toxic substances.

Threat to Aquatic Life — Page 7

1.3.2 The IJC ask the Parties to clarify their interpretation of the Agreement with respect to the development of Lakewide Management Plans. If it is intended that the plans address ecosystem management objectives in order to restore beneficial uses, the SAB recommends that the Parties clarify the rules of inference for establishing causal relationships so that the role of the LaMPs in achieving the restoration goals of the Agreement is made explicit.

1.3.2 The IJC, the Great Lakes Fishery Commission, and the Great Lakes Commission, and their respective staffs hold regular meetings to discuss matters of mutual interest related to the Agreement and its resource management implications.

Evaluation of Sources, Loads, Reductions and Pathways — Page 10

1.3.3 The IJC request the Parties to publically release all available air emissions data for use in the LaMPs. These data, for *all* states and provinces, not just those in the basin, are essential to estimate the role that air sources play in contamination of the lakes.

1.3.3 The IJC request the Parties to ensure that all data collected by the Parties be made available at no cost to the LaMP teams.

1.3.3 The IJC request the Parties to advise LaMP managers that the following actions are needed to ensure that the LaMPs fulfill the requirements of Annex 2:

- solicit and support involvement of scientists to ensure the adequacy of the methodology and data used to estimate the load reductions to be achieved by the LaMPs;
- include existing monitoring data in the estimates of loads;
- identify all atmospheric sources to the lakes;
- estimate the change in chemical burdens in water and fish as a result of key remediation scenarios and include estimates of costs; and
- develop a system for using existing monitoring data.

Surveillance and Monitoring as part of a Larger LaMP Process — Page 11

1.3.4 The IJC challenge the Parties to demonstrate that the LaMP process represents its best management effort in terms of information sharing and dissemination and adequacy of current surveillance and monitoring programs.

Water Quality Criteria — Page 13

1.4.1 The IJC challenge the Parties to demonstrate that their existing policies and programs, such as the Binational Toxic Substances Strategy, will be sufficient to achieve established water quality criteria.

1.4.1 The IJC endorse the bald eagle as an ecosystem indicator for the Agreement and recommend that the Parties commit funding to the long-term monitoring of the population status, trends in concentrations and effects of persistent toxic substances in Great Lakes bald eagles.

1.4.1 The IJC recommend that the Parties select biochemical indicators to monitor trends in exposures of fish, wildlife and human populations to compounds that interact with the aryl hydrocarbon (Ah) receptor, and fund research to develop biochemical assays to determine trends of chemically-induced changes acting through other mechanisms.

1.4.2 The IJC urge the Parties to implement the WHO toxic equivalency factors approach in the development of water quality criteria.

Nonpoint Sources of Pollution to the Great Lakes Basin — Page 20

1.6 The IJC identify to the Parties the need for continued action and vigilance in the control of pollution from nonpoint sources. Such action will be particularly urgent in Areas of Concern where nonpoint sources have been a major contributor to the impairment of beneficial water uses.

1.6 The IJC begin discussions with the Parties to review the adequacy of the phosphorus load reduction targets described in Annex 3 (Control of Phosphorus) of the Agreement, because phosphorous continues to be a concern in the lower lakes.

1.6 The IJC initiate discussions with its advisory boards and the Parties about the significance, sources, biology and pathways of microorganisms arising from nonpoint sources of pollution.

1.6 The IJC urge the Parties to ensure that there are adequate monitoring and surveillance programs for nonpoint sources of pollution, particularly for the evaluation of the effectiveness of specific management actions, for the identification of cause-and-effect relationships and for informed decision making about the control of nonpoint sources.

1.6 The IJC request the Parties to increase funding for research and development of new technologies and techniques for the control of urban and rural nonpoint sources of pollution.

1.6 The IJC urge the Parties to place special emphasis on urbanizing areas; that is, those areas in transition from rural to urban uses. Such land-use changes represent opportunities for implementation of watershed management plans as defined under Annex 13, 2(b), as a condition of their development.

1.6 The IJC request the Parties to report on their implementation of the recommendations for agricultural practices that were published in its Ninth Biennial Report on Great Lakes Water Quality.

Emerging Issues - Aboriginal People — Page 26

1.8 The IJC advise the Parties of the importance of traditional ecological knowledge for understanding the Great Lakes basin ecosystem, and the need to develop mechanisms and processes to ensure that the opportunity to contribute such knowledge is fully provided to aboriginal people and their structures of governance.

1.8 The IJC continue to strengthen its consultations with First Nation, Indian and Tribal governments so as to perform its roles of assisting the Parties in the implementation of the Agreement and in preventing and resolving disputes under the Boundary Waters Treaty.

1.8 The IJC advise the Parties of the need to involve First Nation, Indian and Tribal governments in the institutional arrangements under the Agreement in order to benefit from their knowledge and expertise, and to enhance binational cooperation in its implementation.

Emerging Issues - Coupled Great Lakes Observation and Modeling System **Page 40**

1.8.2 The IJC promote the development of an information technology system basinwide, as a tool for better management and binational cooperation for the Great Lakes.

1.8.2 The IJC advise the Parties to investigate the feasibility and value of a systematic, cooperative approach to applying information technology to the management and research challenges of the Great Lakes and consider research and technology transfer needs in four specific areas:

a) development of a digital Great Lakes computer framework capable of real-time interaction with *in-situ* data from physical, chemical, biological and geological sensors;
b) realistic three-dimensional coastal water-circulation models capable of nowcasting and forecasting;
c) development of distributed computer applications systems that can integrate a variety of multidisciplinary software packages; and
d) development of additional chemical, physical, biological and geological *in-situ* sensors.

WATER QUALITY BOARD RECOMMENDATIONS

Detroit River **Page 57**

2.4 The IJC continue to track progress in habitat management and repair, and that, without adequate attention by the Parties, that part of the Purpose of the Agreement that speaks to biological integrity may not be achieved.

2.4 The Commission recommends to the Parties, appropriate jurisdictions and stakeholders in the Detroit River Remedial Action Plan (RAP), that they take into account the recommendations from the conference into their efforts to further develop and implement remedial and preventive actions to restore impaired uses in the Detroit River.

Contaminated Sediment **Page 59**

2.6.1 The Parties and jurisdictions develop and reach agreement on methods or programs to predict and measure successful ecological recovery in Areas of Concern such as ecological benefit forecasting, monitoring and surveillance programs to measure use restoration.

2.6.1 The Parties and jurisdictions establish procedures for consistent data collection and interpretation across Areas of Concern, recognizing the importance of site specificity in applying methodologies and tools.

2.6.1 Commissioners develop and implement an IJC public outreach strategy to help make contaminated sediment management a priority throughout the basin.

2.6.2 Much greater emphasis be placed on post-project monitoring of the effectiveness of sediment remediation. The assessment of effectiveness relative to restoration of uses with appropriate quality assurance and quality control.

2.6.2 A high priority be placed on monitoring ecological benefits and beneficial use restoration at sites where sediment remediation has taken place.

2.6.2 Additional research is essential to quantify the relationships between contaminated sediment and known use impairments, forecast ecological benefits, and monitor ecological recovery and beneficial use restoration in a scientifically-defensible and cost-effective fashion.

Aquaculture **Page 63**

2.7 Jurisdictions/government agencies perform better site assessments as part of the application for all new caged aquaculture operations, including site specific prediction of carrying capacity (e.g. the University of Minnesota Environmental Assessment Tool could be field tested on new permit/license applications).

2.7 Limit caged aquaculture operations based on a feed quota with specified feed quality.

2.7 A routine monitoring program be required as part of each caged aquaculture license or permit (e.g., benthic community structure, chemistry, periphyton, etc.).

2.7 Best management practices be developed and implemented for all caged aquaculture operations (e.g., an aquaculture operation could be encouraged to obtain ISO 9000 and 14000 certification).

2.7 The Great Lakes Fishery Commission and the International Joint Commission:
- a) continue to track the issue of water quality impacts from Great Lakes aquaculture;
- b) ensure that related aquaculture issues of comprehensive disease management, introduction of exotic species, use of therapeutics and antifoulants be addressed in the future.

2.7 The following research needs be addressed:
- a) development and application of simple, rapid, bioassessment tools and practical early warning indicators for signs of changing benthos, phytoplankton and zooplankton;
- b) development and application of models to estimate carrying capacity and predict site suitability for aquaculture operations;
- c) frequency, extent and feasibility of fallowing or resting a site required to minimize impacts;
- d) nutrient/energy efficiencies of fish feed;
- e) efficacy of alternative nutrient abatement technologies;
- f) impacts of caged aquaculture operations on structure and function of the fishery; and
- g) relative impact of existing land-based aquaculture operations.

2.7 It is recommended that the aquaculture industry:
- a) cage-culture aquaculture applicants assess the carrying capacity of the proposed site and allocate waste loadings within that capacity;
- b) adequate pre- and post-operational monitoring be conducted;
- c) efforts be made to involve all stakeholders early-on (e.g. cottage owners) in planning to gain acceptance and avoid problems;
- d) fish farmers consider using highly digestible, nutrient dense diets that are less polluting and could prove cost-effective for fish production; and
- e) fish farmers consider developing an environmental management system under ISO 14000 that incorporates use of best available technologies and requires adequate monitoring for continuous improvement in operations.

INDICATORS IMPLEMENTATION TASK FORCE RECOMMENDATIONS

10

Page 84

4.6 The IJC use the following Desired Outcomes and indicators for its 10th Biennial Report, and subsequent reporting cycles.

4.6.1 Trends in number of beaches posted/closed because water posed a human health risk over a predetermined swimming season.

4.6.2 Number of added, altered, or lifted fish consumption advisories by Great Lake and by Great Lakes sub-basin.

4.6.3 a) Trends in the number of exceedences of established drinking water standards; and
b) Trends in the number of drinking water restrictions.

4.6.10 The Commission dedicate resources to Indicators application, use and implementation over the next decade because: SOLEC is proposing a staged implementation of indicators; surveillance and monitoring programs will need to be modified and, in some cases, initiated; new and different partnerships (e.g. collaboration with municipal and local governments and agencies) will develop; information management and portrayal (i.e. GIS) will require more attention and organization (i.e. who does what?)

4.6.10 The Commission should consider: ensuring that indicators development continues to be an ongoing IJC priority; maintaining indicator development expertise and momentum by assigning this task to a staff member; working with the Council of Great Lakes Research Managers and the Science Advisory Board to identify and foster research needed to advance our understanding, interpretation and dissemination of indicators; and continuing to collaborate closely with the Parties to reach consensus on a common set of indicators for the Great Lakes, and to implement a binational, integrated monitoring program.

COUNCIL OF GREAT LAKES RESEARCH MANAGERS RECOMMENDATIONS

IAGLR Modeling Summit **Page 96**

5.2.2 Sufficient monitoring programs and coordinated research programs are essential to the development of modeling projects which can provide assistance to managers in addressing pressing management issues.

Survey of Biodiversity and Habitat Goals in the Great Lakes **Page 98**

5.2.4 There is a critical need to develop ecosystem or ecoregional management approaches that protect and enhance critical habitats.

5.2.4 There is a need for U.S. and Canadian coordination for assimilation of biodiversity and habitat research, databases, atlases, cataloguing and other ongoing programs.

Sediment Priority **Page 101**

(concurs with Sediment Priority Action Committee) in the following recommendations)

5.3.1 The Commission recommend to the Parties and Jurisdictions that they develop and reach agreement on methods or programs to predict and measure successful ecological recovery in Areas of Concern (e.g., ecological benefit forecasting, monitoring and surveillance programs to measure use restoration).

5.3.1 The Commission recommend to the Parties and Jurisdictions that they establish procedures for consistent data collection and interpretation across Areas of Concern recognizing the importance of site specificity in applying methodologies and tools.

Endocrine Disruptors **Page 106**

5.3.5 There is an immediate need to put science to service in implementing health intervention and health promotion strategies where necessary.

5.3.5 All strategies should recognize the importance and benefits of fish consumption to particular populations.

Research Vessel Coordination **Page 109**

5.4.1 A system like the University-National Oceanographic Laboratory System (UNOLS) should be used to help coordinate and maximize/optimize use of Great Lakes Research Vessels.

INTERNATIONAL AIR QUALITY ADVISORY BOARD RECOMMENDATION

Page 127

6.5 The IAQAB recommends that the International Joint Commission actively advocate, to the U.S. and Canadian governments, the coordinated use of this or a similar methodology to reexamine current control programs and to identify additional actions necessary to address the goals contained in the Great Lakes Water Quality Agreement and the associated Binational Toxic Strategy for the reduction of inputs of persistent toxic substances, particularly those transported via the atmospheric pathway.

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Chapter One:

THE GREAT LAKES SCIENCE ADVISORY BOARD

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1.1 INTRODUCTION

The Science Advisory Board (SAB/board) led the following activities in support of Commission 1997-99 priorities, and in keeping with its mandate: Annex 2 on Remedial Action Plans and Lakewide Management Plans for Critical Pollutants; Review of Progress of Governments in the Control and Management of Persistent Toxic Substances; and Review and Evaluation of Nonpoint Sources. In addition, the board provided support to: Indicators Implementation Task Force; Contaminated Sediments; and Endocrine Disruptors.

In addition, the board identified a number of emerging issues during the biennial period in keeping with its terms of reference under the Great Lakes Water Quality Agreement (Agreement) to develop ". . . scientific knowledge pertinent to the identification, evaluation and resolution of current and anticipated problems related to Great Lakes water quality."

Several highlights of the board's work over this biennial period are worthy of emphasis. In the human health area, the findings of neurodevelopmental deficits in infants of mothers who ate Great Lakes fish, and the finding of reproductive deficits in exposed populations, continue to support the need for restoration of water quality not only through pollution prevention but more particularly through remedial actions as called for in the Agreement. The board held public meetings to assess the status of progress in the Areas of Concern, and a meeting to *Assess Scientific Issues in Relation to Lakewide Management Plans*, held in February 1999. During these meetings, it became evident that science, policy and communication were disconnected, with the result that planning priorities are not supporting Agreement requirements in some instances. The participants recognized the need for scientists to communicate research findings better, and for managers to fully take into account the policy and program implications of the most current scientific findings. In particular, there are profound implications for public health at current levels of contaminants in the Great Lakes, and therefore a need to consider these implications in the development of Lakewide Management Plans.

Additional highlights of the board's biennial report included the nonpoint source workshop sponsored as a special session at the Great Lakes Soil Erosion and Sediment Control Conference held in Toledo, Ohio in September 1998. Despite the success of managing phosphorous, and new technologies and practices of land stewardship, it is clear that greater efforts are needed to fulfill obligations under Annex 13 (Pollution From Non-Point Sources) of the Agreement.

The identification of emerging issues continues to be an important part of the board's mandate and in this report, four such issues are discussed:

- the relevance of the traditional ecological knowledge of native people, and a role for native governments under the Agreement;
- the need for a coupled Great Lakes observation and modeling system to support management and decision-making challenges in the 21st century;
- results from a basin-wide survey on emerging issues; and
- the emerging risk from increasing nitrogen levels in the lower lakes.

Finally, the board would like to acknowledge the efforts of all of the non-board contributors to this report, many of whom participated as invited experts at board public meetings, industry tours, workshops, and workgroup meetings. They include: William Beamish, Tracey Beauregard, William Booty, Steven Bradbury, Dan Brant, Werner Braun, Roger Brook, Ellen Carpenter, Milton Clark, Mark Cohen, Fraser Craig, Ken Cullis, Joe DePinto, David DeVault, Trevor Dickinson, Jane Dustin, Tom Easterly, Jim Elliott, Frederick Fleischer, Toby Frevert, Roger Gauthier, Ralph Grundel, Heraline Hicks, Raymond Hoff, Paul Horvatin, Michael Hunter, Dean Jacobs, Peter Johnson, David Kallander, William Karazov, Wilfried Karmous, Joan Karnauskas, Robert Kent, Renate Kimbrough, Tim Kubiak, Paul Labus, Amanda Laumeyer, Joseph LeBeau, Terry Logan, Orie Loucks, Stephen Lozano, Frederick Luckey, Don Marles, Ann McCammon Soltis, Barbara McElgunn, Rick Menozzi, Ken Mentzel, Dave Miraldo, Donna Myers, Scott Painter, Noel Pavlovic, Dave Pfeifer, Bowden Quinn, Henry Regier, Mark Reshkin, Michele Riband, Deborah Rice, Jeff Ridal, William Riley, Larry Schleen, Greg Searle, Thomas Schueler, Greg Sherbin, Adam Socha, Douglas Spry, Rod Stewart, Michael Stewart, Paul Stewart, Scott Stoner, Deborah Swackhammer, Dave Tomlinson, Garry Traynan, Thomas Tseng, Jack Vallentyne, Chris van Netten, Donald Waller, Glenn Warren, Chip Weseloh, Richard Whitman, Janice Whitney, Paul Williams, Al Wright, and Bob Yrojola.

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1.2 RECOMMENDATIONS

1997-1999 SCIENCE ADVISORY BOARD RECOMMENDATIONS

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- include existing monitoring data in the estimates of loads;
- identify all atmospheric sources to the lakes;
- estimate the change in chemical burdens in water and fish as a result of key remediation scenarios and include estimates of costs; and
- develop a system for using existing monitoring data.

(1.4) The IJC challenge the Parties to demonstrate that the LaMP process represents its best management effort in terms of information sharing and dissemination and adequacy of current surveillance and monitoring programs.

(1.4) The IJC challenge the Parties to demonstrate that their existing policies and programs, such as the Binational Toxic Substances Strategy, will be sufficient to achieve established water quality criteria.

(1.4) The IJC endorse the bald eagle as an ecosystem indicator for the Agreement and recommend that the Parties commit funding to the long-term monitoring of the population status, trends in concentrations and effects of persistent toxic substances in Great Lakes bald eagles.

(1.4) The IJC recommend that the Parties select biochemical indicators to monitor trends in exposures of fish, wildlife and human populations to compounds that interact with the aryl hydrocarbon (Ah) receptor, and fund research to develop biochemical assays to determine trends of chemically-induced changes acting through other mechanisms.

(1.4) The IJC urge the Parties to implement the WHO toxic equivalency factors approach in the development of water quality criteria.

(1.6) The IJC identify to the Parties the need for continued action and vigilance in the control of pollution from nonpoint sources. Such action will be particularly urgent in Areas of Concern where nonpoint sources have been a major contributor to the impairment of beneficial water uses.

(1.6) The IJC begin discussions with the Parties to review the adequacy of the phosphorus load reduction targets described in Annex 3 (Control of Phosphorus) of the Agreement, because phosphorous continues to be a concern in the lower lakes.

(1.6) The IJC initiate discussions with its advisory boards and the Parties about the significance, sources, biology and pathways of microorganisms arising from nonpoint sources of pollution.

(1.6) The IJC urge the Parties to ensure that there are adequate monitoring and surveillance programs for nonpoint sources of pollution, particularly for the evaluation of the effectiveness of specific management actions, for the identification of cause-and-effect relationships and for informed decision making about the control of nonpoint sources.

(1.6) The IJC request the Parties to increase funding for research and development of new technologies and techniques for the control of urban and rural nonpoint sources of pollution.

(1.6) The IJC urge the Parties to place special emphasis on urbanizing areas; that is, those areas in transition from rural to urban uses. Such land-use changes represent opportunities for implementation of watershed management plans as defined under Annex 13, 2(b), as a condition of their development.

(1.6) The IJC request the Parties report on their implementation of the recommendations for agricultural practices that were published in its Ninth Biennial Report on Great Lakes Water Quality.

(1.8) The IJC advise the Parties of the importance of traditional ecological knowledge for understanding the Great Lakes basin ecosystem, and the need to develop mechanisms and processes to ensure that the opportunity to contribute such knowledge is fully provided to aboriginal people and their structures of governance.

(1.8) The IJC continue to strengthen its consultations with First Nation, Indian and Tribal governments so as to perform its roles of assisting the Parties in the implementation of the Agreement and in preventing and resolving disputes under the Boundary Waters Treaty.

(1.8) The IJC advise the Parties of the need to involve First Nation, Indian and Tribal governments in the institutional arrangements under the Agreement in order to benefit from their knowledge and expertise, and to enhance binational cooperation in its implementation.

(1.8) The IJC promote the development of an information technology system basinwide, as a tool for better management and binational cooperation for the Great Lakes.

(1.8) The IJC advise the Parties to investigate the feasibility and value of a systematic, cooperative approach to applying information technology to the management and research challenges of the Great Lakes and consider research and technology transfer needs in four specific areas:

- development of a digital Great Lakes computer framework capable of real-time interaction with *in-situ* data from physical, chemical, biological and geological sensors;
- realistic three-dimensional coastal water-circulation models capable of nowcasting and forecasting;
- development of distributed computer applications systems that can integrate a variety of multidisciplinary software packages; and
- development of additional chemical, physical, biological and geological *in-situ* sensors.

1.3 SPECIAL MEETING TO ASSESS SCIENTIFIC ISSUES IN LAKEWIDE MANAGEMENT PLANS FOR CRITICAL POLLUTANTS

The 1987 Protocol amending the 1978 Great Lakes Water Quality Agreement contains a renegotiated Annex II concerning Remedial Action Plans and Lakewide Management Plans. The International Joint Commission was given the responsibility of reviewing and commenting on plans that were submitted to the Commission. In the 1997-1999 Revised Priorities of the Commission concerning the work to be undertaken by the boards under the Great Lakes Water Quality Agreement, the Commission requested advice on the adequacy of the plans. The Great Lakes Science Advisory Board organized a Meeting to Assess Scientific Issues in Relation to Lakewide Management Plans; it was held on February 25 and 26, 1999. It was organized following the format in Annex 2 of the Agreement as follows: Definition of the Threat to Human Health; Definition of the Threat to Aquatic Life; Evaluation of Sources, Load Reductions and Pathways; and Surveillance and Monitoring to Track Effectiveness.

1.3.1 Definition of the Threat to Human Health

Research findings indicate that critical subpopulations continue to be exposed to persistent toxic substances (PTSs), particularly from fish consumption as the major pathway of exposure. Increased fish consumption is associated with body burdens of persistent toxic substances that are two to four times greater than in the general population. Many men and women consume Great Lakes fish during most of their reproductive years resulting in exposures to persistent toxic substances from the Great Lakes that cause disturbances in reproductive parameters (Courval et al. 1999) and demonstrate neurobehavioural and developmental deficits in newborns (Jacobson et al. 1985; Jacobson and Jacobson 1993, 1996; Lonky et al. 1996) and cancer (Moysich et al. 1999). The more highly exposed subpopulations include anglers, particularly among the urban poor, commercial fishermen, charter boat captains, Native Americans, and particular ethnic groups such as Hmong and Vietnamese immigrants. The more susceptible ones include pregnant women, fetuses and nursing infants, children and the elderly (Johnston et al. 1998; De Rosa et al. 1999).

The participants acknowledged that the preparation of a Lakewide Management Plan is a difficult task, and particularly as it relates to defining the threat to human health from critical pollutants. First, it was acknowledged that there is little political will (Great Lakes Water Quality Board 1993) to prepare such coherent statements because of liability concerns and because the costs of clean up are substantial. The fact is, the general population does not like paying higher taxes or higher prices and it is ultimately society, in general, that is the source of political pressure. But at the technical level, it was recognized by participants that there is a more subtle difficulty. The medical profession is organized mainly on the basis of responding to individuals who present themselves at the doctor's office with a disease or disorder to be treated. In contrast, exposure to pollutants tends to have effects on populations and particularly on the normative functioning of individuals within the population (International Joint Commission 1994). The loss of five or six I.Q. points in the most highly exposed individuals in a critical subpopulation cannot be diagnosed. Thus, there is a need to expand the definition of human health beyond the disease model and to include consideration of functional capacity. For example, a downward shift in the mean I.Q. of an exposed subpopulation could represent a loss of intellectual capacity with significant economic and social consequences. This is due in part to the fact that a small shift in the mean of a distribution can have a profound effect on those individuals in the tails of the distribution (Weiss 1997; Great Lakes Science Advisory Board 1997).

The fact is, the general population does not like paying higher taxes ... and it is ultimately society, in general, that is the source of political pressure.

Community Health and Endocrine Disruptors

Epidemiology is a rational approach to studying the incidences and causes of diseases. However, it may not be a particularly feasible method for investigating dysfunction within a community. Not only may the statistical requirements be particularly stringent resulting in surveys requiring large sample sizes, but also estimates of exposures to pollutants can be unreliable or unavailable. There are factors other than environmental exposures that are determinants of human health, including: genetics, lifestyle, psychological factors, socio-economic factors and how individuals interact with the health care system. The teratogenic effects of environmental pollutants are unlikely to arouse the apprehensions of clinicians because they are both subtle and non specific, even though they are significant for the exposed subpopulations (Colborn and Clements,1992; Colborn et al. 1998, 1999; Johnson et al. 1998; De Rosa et al. 1999).

Health authorities in both countries have acknowledged the need for an official response to the perception within communities that they have been exposed to chemicals and that health has been affected. Generally, this is not a priority issue with local or regional levels of government compared with traditional public health concerns. There is a perception at the local community

level, among those involved in the preparation of the Remedial Action Plans and the Lakewide Management Plans, that there is no mechanism for gathering the information needed by the physicians and health authorities at the local level, to document what is occurring as a result of exposures to contaminants. Much of the evidence is anecdotal and concerns reports of effects on children and is therefore delivered in an emotional manner without objectivity, and with great fear and trepidation and by people who are suffering. One central question is whether clusters of health effects indicate unusual exposures.

In the United States, the Agency for Toxic Substances and Disease Registry, which is part of the Public Health Service, may be called in by the state authorities to undertake a health and exposure survey. In Canada, the responsibility for health protection is a provincial responsibility. Health Canada has integrated existing information on the risks to human health, and as part of the Great Lakes Health Effects Program, compiled a handbook detailing a community-based approach to undertaking exposure assessments. The challenge is how to utilize these approaches to community health in preparing Lakewide Management Plans and Remedial Action Plans. For example one of the issues brought up by several LaMP managers was the problem of scale, and the question of whether human health questions could be addressed at the local, rather than the regional and national levels. Are the health and exposure issues in a community likely to be different from another community 50 or 100 km away? Much of the information available is collected at the national or regional level and does not give the detail required to assess health effects at the local level. Similarly, there is a need for outreach, by federal, state and provincial health authorities, to the communities communicating the significance of the information at the regional and local levels for preparation of the Lakewide Management Plans and the Remedial Action Plans.

Fish Advisories

For the past 30 years, the response to the finding of dangerous levels of pollutants in fish has been to close commercial fisheries and to publish fish advisories concerning the quantity and frequency of consumption of different sport fish species that could be eaten from a particular location. In 1993, the Council of Great Lakes Governors appointed a panel to establish uniform fish advisories that were to be both consistent among jurisdictions and protective of human health. Similarly, the Province of Ontario publishes an annual Guide to Eating Ontario Sport Fish. All of the Great Lakes waters in the U.S. have some kind of advisory. In 1996, the most recent year for which there are national data, the number of U.S. bodies of water with advisories rose by 453 to a total of 2,193, representing a 26 percent increase over 1995. In Canada, 2,617 advisories were in effect in 1996, and all resulted from contamination with one or more of five pollutants: mercury, PCBs, dioxins/furans, toxaphene and Mirex. While the various advisories generally contain useful information, there is no information about the effects of these pollutants on human health if larger amounts of fish are consumed. Surveys have been undertaken of the effectiveness of fish advisories as a means of protecting human health. In one study, awareness of the fish advisories was especially low among women, suggesting the need for improved communication of the information to female consumers (Tilden et al. 1997).

Based on the weight of evidence (Colborn and Clements 1992; Colborn et al. 1998, 1999; Johnson et al. 1998; De Rosa et al. 1999), the Great Lakes Sciences Advisory Board concludes that:

- some humans in the Great Lakes basin continue to be exposed, primarily through consumption of Great Lakes fish, to levels of persistent toxic substances sufficient to cause adverse health effects; and

- while levels of persistent toxic substances have declined in the Great Lakes (Science Advisory Board 1997), the scientific understanding of the implications of exposures to these substances has increased such that there is now a broader range of concerns for effects on human health. There is a need for the development of a methodology to assess the effects of endocrine disruptors on community health.

The SAB recommends the following.

- **The IJC advise the Parties to collaborate on the preparation of a comprehensive statement, for the entire Great Lakes basin, of the threat to human health posed by critical pollutants and that this comprehensive assessment be used in the preparation of Lakewide Management Plans.**

- **The IJC urge the Parties to increase consultation between health authorities and local communities to assist them, and particularly vulnerable subpopulations, to discern whether adverse effects, either overt or subtle, are occurring due to their exposures to persistent toxic substances.**

1.3.2 Definition of The Threat to Aquatic Life

Contrasting Approaches

The session on the threat to aquatic life was dominated by the contrasting approaches of the fish and wildlife researchers. While there have been demands that those responsible for the preparation of the LaMPs incorporate existing science into the documents, several factors have prevented this being done in a competent and timely manner, including the availability of qualified staff familiar with the scientific literature and the institutional arrangements. The most important factor, however, has been the ambiguity about whether the Lakewide Management Plans shall be designed to reduce loadings of critical pollutants or whether they shall embody a systematic and comprehensive ecosystem approach in restoring and protecting beneficial uses.

A small number of scientists have been investigating the effects of critical pollutants on fish and wildlife populations in the Great Lakes basin, during the past 40 years. In the 1960s and 1970s, they reported the gross effects of persistent toxic substances on the reproduction and development of wildlife and in ranch mink dependent on Great Lakes fish. Wildlife populations that have been affected by exposures to persistent

toxic substances are generally non-game species, and are not managed as a resource. Consequently, the number interested is relatively small and their influence is limited. Effective action has traditionally depended on preparing a scientifically defensible case relating the injury to wildlife populations to a specific substance or class of substances and subsequently persuading the regulatory officials to take the necessary steps to prohibit the activities involving the substance. This approach has resulted in the successful restoration of many populations of wildlife species extirpated by exposures to persistent toxic substances, but not for certain sensitive species in areas, such as Lake Ontario, that remain heavily contaminated.

In contrast, a large number of scientists are involved in research, monitoring and management of fisheries populations in the Great Lakes. There have been extensive changes in species composition that are generally expressed, since the 1970s, in ecological terms. Management objectives are formulated in terms of losses and gains in biodiversity, relating to extinctions and introductions respectively, and to changes in ecosystem structure and function, sustainability and balance, and are based on the four major categories of threats to Great Lakes fisheries: introduced flora and fauna; habitat destruction; overfishing; and proliferation of fish diseases (Hartman 1988). In contrast to non-game wildlife, Great Lakes fisheries management is of interest to many parties. Fisheries managers perceive that the greatest challenge to planning and management in the Great Lakes basin is maintaining a sense of balance among the various ecological, social and political systems involved. Fisheries managers believe that the greater the number of people with an interest who get involved in the process, the greater the likelihood of success. Fisheries management in the Great Lakes is a mature consultative process.

The contrast between the toxicological approach of the wildlife biologists and the ecological approach of most fisheries researchers is reflected in the advice given to managers involved in the preparation of the Lakewide Management Plans, and in the interpretation of the Agreement implementation. The toxicological approach is aimed at identifying the specific substance or class of substances that caused the observed injury to the wildlife, whereas the ecological approach is directed toward describing the many factors that may be stressing the populations.

The issue of causality lies at the heart of the definitions for the Lakewide Management Plans. There are extensive case studies that have been prepared relating the observations of reproductive failure and deformities in wildlife to exposures to critical pollutants such as DDT and metabolites, PCBs, and dioxins. These case studies have been prepared using the criteria incorporated by the United States Environmental Protection Agency (U.S. EPA 1992) into the guidelines for ecological risk assessment.

The ecological interpretation of the Agreement is based on the premise that changes in Great Lakes fish populations resulted from the cumulative impacts of many stressors including the introduction of exotic species, habitat changes, eutrophication, overfishing, proliferation of fish diseases and selective stocking of sport fish. Fisheries ecologists have not been able to ascertain whether all the changes in the Great Lakes fisheries were the results of many factors acting in concert at the local level or whether some indigenous species in certain locations were made extinct through a single factor, or through a primary factor acting in concert with other stressors.

A Challenge to the Multi-Causal Explanation

In the past decade there has been a challenge to this multi-causal explanation of the changes in the fisheries populations in the Great Lakes. With evidence of the presence of high levels of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in Lake Ontario, in the early 1980s, and the availability of an established methodology for risk assessment, researchers studied several lines of evidence to undertake a retrospective risk assessment of the effects of dioxin on Lake Ontario lake trout. The Lakewide Management Plan, prepared concerning Lake Ontario, concluded that the "contribution of persistent toxic substances to the loss of certain fisheries is unclear because fish populations were already severely degraded by the time that significant levels of contaminants began to be released to the environment." If Cook et al. (1997) have interpreted the evidence correctly, then this LaMP conclusion warrants reassessment.

The data on the harvesting of lake trout from Lake Ontario reveal that there was a decline in the status of the population that started about 1880. Through the stocking of hatchery-reared fry, there was a large population increase in the early 1900s, and a maximum harvest of nearly five hundred thousand kilograms in 1928. These data indicate several important factors in the exploitation of the lake trout stocks in Lake Ontario.

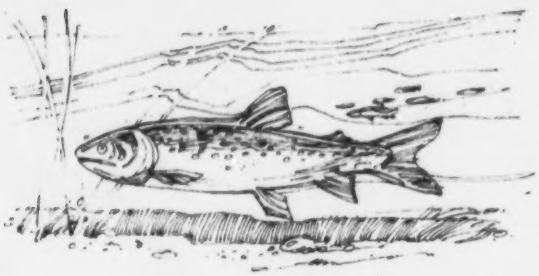
- Stocks of lake trout can be drastically reduced by commercial harvesting.
- Stocking with millions of fry can support a commercial harvest that would otherwise be unsustainable.
- The presence of the sea lamprey, historically, does not seem to have significantly reduced lake trout numbers in Lake Ontario.
- The commercial harvest data indicate that the adult lake trout produced from the stocked fry were able to reproduce in the 1930s and that their progeny survived.
- The removal of most of the stocking program in the 1920s and the continuation of the harvest was a major contribution to the rapid decline of the lake trout population through the 1930s.

The probable concentrations of PCDDs, PCDFs and PCBs in the Lake Ontario lake trout eggs have been reconstructed retrospectively back to 1920. The results were used with the accumulation factors from sediment to biota adjusted for historical trends in contaminant distribution between water and sediment. There was a sharp rise in the probable concentration starting as early as the 1930s and continuing to a peak in the late 1960s. Toxicological evidence from experimental exposure of eggs of lake trout to 2,3,7,8-tetrachlorodibenzo-*p*-dioxin has, surprisingly, shown that the early life stages of this species are extremely sensitive to this compound. The decline in Lake Ontario lake trout populations after 1940 was inversely correlated with the increasing exposures to TCDD toxicity. The toxicity of TCDD and related chemicals in Lake Ontario was estimated to have completely eliminated the capability for lake trout reproduction and recruitment by 1950 (Cook et al. 1997).

The demise of the Lake Ontario lake trout poses the question whether other species were extirpated from Lake Ontario by this same cause. For example, the deep-water sculpin, which was the natural prey of the lake trout in the profundal area was apparently extirpated by the 1960s, and the populations of

burbot, lake herring and lake whitefish practically disappeared. The information assembled on these contaminants provides a hypothesis to apply to historical data on other populations of other fish species in other Great Lakes that were extirpated during this century.

Undoubtedly, other stressors, such as the continuation of a commercial fishery, together with the depredations of the sea lamprey may have contributed to the declines in the Lake Ontario lake trout population. Similarly, other stressors such as alewife predation on fry, may contribute to the present difficulty in reestablishing naturally reproducing populations of Lake Ontario lake trout. The important corollary for research managers arising from the conclusion of Cook et al. (1997) is



whether other stressors acting in concert at the local level could have brought about the extinction of the stocks of Lake Ontario lake trout. This toxicological hypothesis (Cook et al. 1997) strongly suggests that the TCDD toxicity alone would have caused the extinction of this Lake Ontario species, as was observed in the early 1960s. Similarly, this toxicological hypothesis, which closely conforms to the classes of evidence relating exposures to persistent toxic substances and effects in wildlife populations, challenges multi-causal ecological assumptions and statements, that are now being used as the basis for the preparation of the Lakewide Management Plans.

Differing Interpretations of the Great Lakes Water Quality Agreement

The purpose of the 1978 Agreement "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" by eliminating or reducing the discharge of pollutants, was ascertained by Oakley in the *Review of the Changes in the 1978 Great Lakes Water Quality Agreement* (1979) to be an agreement on water quality, and not to be an agreement on ecosystem management. In 1985, the National Research Council of the United States and the Royal Society of Canada viewed the Agreement as *An Evolving Instrument of Ecosystem Management* (NRC and RSC 1985). Session participants also held differing views as to the intent and implementation of the Agreement. Some maintained that the Agreement is an instrument of ecosystem management and provides an appropriate and effective mechanism for accommodating a multitude of issues associated with the restoration of the integrity of the waters of the Great Lakes Basin Ecosystem. Others argued that its intent is focused more specifically on critical pollutants, and that a broader focus can limit progress by reducing resources available to address specific initiatives such as LaMPs. In this latter view the Agreement was never intended to be an instrument of ecosystem management; therefore it has inherent limitations, both in terms of its scope and its institutional capabilities, to achieve a broader purpose. Similar differences of opinion arose among the meeting participants as to whether the primary goal of a LaMP is to restore beneficial uses or to reduce loadings of critical pollutants.

The SAB recommends the following.

- **The IJC ask the Parties to clarify their interpretation of the Agreement with respect to the development of Lakewide Management Plans. If it is intended that the plans address ecosystem management objectives in order to restore beneficial uses, the SAB recommends that the Parties clarify the rules of inference for establishing causal relationships so that the role of the LaMPs in achieving the restoration goals of the Agreement is made explicit.**

The SAB recognizes that there are certain resource management issues that relate directly to water quality, such as the restoration of fish populations extirpated by releases of PTSs (Cook et al. 1997), or the impact of agricultural practices on water quality (Great Lakes Commission 1996). At the same time, fisheries management activities take into account many factors that some consider to have a less direct relationship to the Agreement *per se*, but which might benefit from coordinated action or discussion, for example, fish stocking. Similarly, other Great Lakes institutions, such as the Great Lakes Commission, conduct a broad range of program and management reviews that could provide a basis for greater Commissioner, or staff, interaction with the IJC.

The SAB recommends the following.

- **The IJC, the Great Lakes Fishery Commission, and the Great Lakes Commission, and their respective staffs hold regular meetings to discuss matters of mutual interest related to the Agreement and its resource management implications.**

1.3.3 Evaluation of Sources, Loads Reductions and Pathways

Overview

The panel on sources, load reductions and pathways included experts on the utilization of existing data, on the generation of new data from surveys, and on modeling. Its comments focused on scientific challenges that they considered crucial to reducing loadings of critical pollutants in the Lakewide Management Plans. The topics discussed included: the role of zebra mussels on predictions of fish burdens; the availability of atmospheric monitoring data; access to industrial emissions data; the relative importance of contaminated riverine sediments; and the role that the LaMP process can play in improving the scientific understanding of toxic cycling in the lakes. Several important conclusions appeared to reflect consensus. Furthermore, many of the conclusions reached showed enthusi-

asm for the LaMP process and the panelists' optimism about the LaMPs' potential for success in achieving progress. The recommendations summarized below focus on specific actions that need to occur to ensure this success.

Scientific Issues that the LaMPs Should Consider

All the panelists recognized the effort involved in the development and implementation of the Lakewide Management Plans. While difficult, the identification of sources and decisions about actions for reducing loads are not without precedent. Their discussion included many examples of issues that had been previously considered or examined through scientific efforts.

Because most of the panelists are not involved directly in any of the LaMPs, the discussion focused on matters of science rather than planning issues. The panel was concerned that their comments not be construed as criticism, but rather as suggestions and scientific advice from experts knowledgeable about toxics behaviour in the lakes. Four issues are highlighted from the discussion as follows.

1. Several panelists noted that existing toxics data were not readily accessible for use in the LaMPs. Examples of these data sets include the results of previous monitoring of toxics in fish, water and near potential sources. While most of this data has been collected or funded by the Parties, it is not in an organized data base, and it has not been collected or organized in a coordinated manner. Since the data are not well organized and/or evaluated for quality, they are difficult for the LaMP managers to use. Atmospheric data may be an exception. The data collected under the Integrated Atmospheric Deposition Network are unusually well coordinated between the Parties and are available for use, as are the long-term data of the Canadian Wildlife Service on pollutants in fish-eating birds. In addition to monitoring data, atmospheric emissions information also exists and could be of great value to the LaMP efforts if made available. Using this data, the sources of atmospheric toxics to the lakes could be identified and quantified.

2. The panelists commented on the relative importance of atmospheric deposition of toxic substances. It is thought that atmospheric sources of toxic substances are among the largest contributors to the lakes and that they are a source that can be easily controlled and reduced. Identification of industrial, agricultural and municipal/urban sources is entirely feasible and can be incorporated into the LaMP activities of identifying possible reductions and specific sources.

3. The role of atmospheric sources will *increase* over time, not decrease or remain constant. This is because the net input of gas phase air pollutants depends on the ratio of air concentration to water concentration. As the water concentrations are reduced, atmospheric inputs will increase, thereby buffering the observed water concentrations, unless something is done to decrease atmospheric sources. Other activities to reduce toxic substances in the open lake will have limited effect as long as atmospheric input remains uncontrolled.

4. The goals of the various local remedial activities may be considered from an open-lake perspective. Generally, the transport of contaminated sediments to the open lake occurred in the past, and currently may represent only a small fraction of the total pollutant load to the lake. In addition, some in-lake processes (sedimentation, biological degradation, volatilization) reduce the concentrations of critical pollutants. Other processes, such as filtering of particles by zebra mussels, may increase the availability of toxic substances to fish, even though water concentrations decline. While dredging of contaminated sediments in nearshore areas may still provide local benefits, its effect on open-lake concentrations of critical pollutants is uncertain. Regulation of air sources, including those outside the Great Lakes basin, could be the most effective single action to achieve reduced loadings, notwithstanding the relative importance of other sources, including direct discharges, and contaminated sediments.

The SAB recommends the following.

- **The IJC request the Parties to publically release all available air emissions data for use in the LaMPs. These data, for *all* states and provinces, not just those in the basin, are essential to estimate the role that air sources play in contamination of the lakes.**

- **The IJC request the Parties to ensure that all data collected by the Parties be made available at no cost to the LaMP teams.**

- **The IJC request the Parties to advise LaMP managers that the following actions are needed to ensure that the LaMPs fulfill the requirements of Annex 2:**

  - **solicit and support involvement of scientists to ensure the adequacy of the methodology and data used to estimate the load reductions to be achieved by the LaMPs;**

  - **include existing monitoring data in the estimates of loads;**

  - **identify all atmospheric sources to the lakes;**

  - **estimate the change in chemical burdens in water and fish as a result of key remediation scenarios and include estimates of costs; and**

  - **develop a system for using existing monitoring data.**

1.3.4 Surveillance and Monitoring to Track Effectiveness

In the expert panel on Surveillance and Monitoring, eight experts presented their views on the relevant scientific issues. The presentations covered a wide range of topics including the design and intended uses of data from surveillance and monitoring programs. Several key themes emerged as follows.

Implications of Fiscal Restraint on Surveillance and Monitoring Programs

Many speakers made reference to the serious budget cuts that have occurred in Great Lakes programs over the past decade. For many agencies, these cuts have forced a fundamental reconfiguration of surveillance and monitoring programs. Sometimes, this reconfiguration has been reflected in reduced monitoring frequency or spatial coverage. In other programs, there has been a conscious decision to move away from large-scale lakewide programs toward local studies that can provide more detailed and accurate loading estimates, but which fail to provide a regional or lakewide perspective. Long-term programs focusing on key indicator species have received less funding and attention in recent years, to the detriment of our being able to track temporal and spatial trends.

Several speakers emphasized the point that the lakes themselves are dynamic systems, completely apart from actions that may change pollutant loadings to them. Dramatic food web changes have already been documented in some systems, and these changes are thought to be the result of complex phenomena, probably including, but not limited to pollutant loading changes. There is a need for ongoing adaptation of surveillance and monitoring programs so that they are responsive to the dynamic nature of the lakes.

The SAB recommends the following.

- *The IJC request the Parties to publically release all available air emissions data for use in the LaMPs. These data, for all states and provinces, not just those in the basin, are essential to estimate the role that air sources play in contamination of the lakes.*

Data Used for Many Purposes

It is apparent that under the prevailing climate of fiscal restraint, few programs have the resources to collect data for a single purpose. Rather, most agencies are collecting data that may be used for many purposes, some of them not intended when the program was designed. Most LaMPs must therefore patch together data from a variety of sources, and of varying ages and analytical methodologies, and try to interpret them in a lakewide context. This has been a challenging task, especially since LaMPs are required to track the effectiveness of remedial measures and the impacts on beneficial uses of critical pollutants. To complicate interpretation, much of the available data is not in a form that is readily understood by most LaMP participants. As a result, data may be misinterpreted or simply ignored as unusable. Many scientists who spoke at the session, both those on the panel and those in the audience, expressed concern that LaMPs may contain outdated or incomplete information, and where that occurs may convey an inaccurate or misleading message. They believe that the LaMPs are significantly weakened by the omission of current and valuable, if highly technical, data.

Those participants with LaMP planning responsibilities had a different perspective on this problem. They agreed that the LaMP analysis may be less complete and/or less accurate than desirable, if critical information is omitted. They stated, however, that their frustration arises in trying to make sense of scientific data without the close involvement of the scientific community. They spoke of their attempts to piece together a mosaic of data, little of it collected for the LaMP effort, and of trying to make sense of information that is contradictory, confusing or simply unintelligible.

Surveillance and Monitoring as Part of a Larger LaMP Process

Several speakers made reference to the complex interactions between a LaMP, the scientific community and regulatory agencies. Some of the dissatisfaction that was expressed about the LaMP process may in fact be a result of confusion about an appropriate division of responsibilities and an appropriate mechanism for consultation among the various players legitimately involved in LaMP-related activities.

Three key roles emerged from the workshop discussion.

1. The scientific community has a responsibility to assist in the identification of critical pollutants, conduct exposure and toxicological analysis, interpret and disseminate results, and advise on the fate and pathways of critical pollutants in the environment. This *science* step must involve not only cellular and molecular scientists, but also field ecologists who can assist in evaluating ecosystem-level impacts. Several speakers made the point that only the scientists can properly interpret their data. In other words, it is not appropriate to ask LaMP participants to analyze and interpret raw data collected by others; to do so could lead to serious errors of interpretation. However, it is clearly not enough to have scientists analyze data and then present a brief seminar or simply ask LaMP members to read a scientific paper on the results. Information must be presented in a way that is accessible to LaMP participants and which permits an exchange of ideas about implications and potential action.

2. Regulatory agencies, who conduct surveillance and monitoring programs, collate and manage data, and enforce legal requirements. They must be up to date on major developments in environmental toxicology and chemical behaviour, and in aquatic ecology, so as to be able to adapt monitoring activities to respond to new information needs. Good communication between scientists and regulatory agencies is also necessary so that appropriate detection limits are used. Weak data, high detection limits and/or inadequate interpretation can mean that findings are simply dismissed as guesswork. One speaker emphasized the point that loading estimates must be accurate and defensible, because they will eventually be used to persuade agencies and private sector companies to spend large amounts of money on remedial measures.

3. LaMP managers should use the results of scientific investigations and monitoring data to influence management decisions. Other social, cultural and economic factors may also affect a LaMPs preferred management strategy. One speaker therefore compared this process to a risk management process, in which decisions are made about managing a known risk, rather than a risk assessment process, which is more the province of the scientific community. The decisions made by the LaMP team in turn create a need for ongoing surveillance and monitoring, especially tracking the effectiveness of remedial measures and estimation of pollutant loadings. In this sense, the LaMP should ideally help to set the objectives for the application and use of data, and determine the level of compatibility and coordination needed with other programs. These responsibilities therefore create a need for effective communication between the LaMP's team and the regulatory agencies.

The scientific community has a responsibility to assist in the identification of critical pollutants, conduct exposure and toxicological analysis, interpret and disseminate results, and advise on the fate and pathways of critical pollutants in the environment. This science *step must involve not only cellular and molecular scientists, but also field ecologists who can assist in evaluating ecosystem-level impacts.*

Scientists, regulatory officials and LaMP participants need to meet on a regular basis to identify the critical pollutants to be managed through the LaMP process. It was equally clear that the current level of interchange among the three groups is inadequate to support effective progress on LaMPs.

The SAB recommends the following.

- **The IJC challenge the Parties to demonstrate that the LaMP process represents its best management effort in terms of information sharing and dissemination and adequacy of current surveillance and monitoring programs.**

1.4 WATER QUALITY CRITERIA WORKSHOP

1.4.1 Review and Progress of Governments in the Control and Management of Persistent Toxic Substances: Development and Use of Water Quality Objectives

In December 1997, the International Joint Commission directed the Great Lakes Water Quality Board, Great Lakes Science Advisory Board and the Council of Great Lakes Research Managers to assess governments' efforts to further determine the impact of persistent toxic substances on the Great Lakes, develop a control and prevention strategy, and advise on strategies of the governments in the implementation of the control and management programs for discharges of persistent toxic substances.

The Great Lakes Science Advisory Board held a workshop in Chicago at the Regional Headquarters of the U.S. Environmental Protection Agency, in March 1998. It discussed the adequacy of existing water quality objectives for protection of organisms, including humans, living in the Great Lakes basin exposed to persistent toxic substances from Great Lakes food chains. This section of the report is based on selected technical presentations, and interrelates the protection of human health with the restoration of extirpated Great Lakes wildlife populations, and the implementation of the Agreement. Parts of this report were published as a brief meeting report in the March 1999 issue of *Environmental Health Perspectives.*

Article IV of the Boundary Waters Treaty of 1909 that states in part "that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." One of the key ideas in the Agreement is that water quality can be maintained and restored by developing and adopting water quality objectives. This idea was incorporated into the first Agreement, signed in 1972. The rationale is that if scientists could recommend the concentration of a pollutant that could be tolerated by organisms in the Great Lakes, then engineers could build and operate waste treatment facilities to make sure that the pollutant stayed below that concentration. This rationale has been successfully used by governments to improve water quality in the Great Lakes basin for more than 40 years.

In 1978, with the renegotiation of the Agreement the Parties amended the policy regarding toxic substances by stating that the "discharge of any and all persistent toxic substances be virtually eliminated." Water quality objectives for both toxic substances and persistent toxic substances were incorporated into Annex 1. **However, no specific definition of virtual elimination of discharge of persistent toxic substances has been developed for the Agreement.**

To what extent has the policy been achieved and are additional actions needed? Persistent toxic substances continue to leach from chemical landfill sites and from contaminated sediments (U.S. EPA and NYSDEC,1997; Lakewide Management Plan for Lake Ontario 1998) and be deposited from the atmosphere (Cohen et al. 1995; Hoff et al. 1996), thereby maintaining concentrations high enough to continue to cause injury to fish, wildlife and human populations. Existing water quality objectives need to be reevaluated to determine whether they are sufficiently stringent to restore affected fish and wildlife populations, to protect human health and to fulfill the requirements of the Parties' policy of virtual elimination of discharge.

Injury to Human Health and to Fish and Wildlife Populations

The research on the reproduction of wildlife and on the developmental effects in infants exposed to persistent toxic substances pointed to the widespread presence of teratogenic substances that are causing irreversible transgenerational damage. These case studies were subsequently important in the formulation of the hypothesis on endocrine disruption that has become an explanatory principle in modern environmental toxicology (Cheek et al. 1998; U.S. Environmental Protection Agency 1997, 1998; Scientific Committee on Toxicity, Ecotoxicity and the Environment 1999). The various stages of the normal differentiation and development of the embryo, fetus and infant are under the control of specific chemical messengers that are programmed to be released from a certain tissue, transported in the blood, and produce specific effects at a certain concentration and particular time in another tissue or organ. The scientific community has recently become focused on the finding that some chemicals, including many persistent toxic substances that have been released to the environment, interfere with these chemical messengers and cause irreversible damage to the developing embryo and fetus. These effects occur at extremely low doses (Peterson et al. 1992; Welshons et al. 1999; Colborn et al. 1999) and include changes in the development and function of the reproductive system, deficits in neurological development affecting learning and deficits in the development of the immune system.

In the 1990s, the U.S. and Canadian governments have made significant progress in developing water quality objectives and criteria for persistent toxic substances. For example, in response to the Great Lakes Critical Programs Act of 1990, the U.S. Environmental Protection Agency developed water quality criteria for persistent toxic substances, under the Great Lakes Initiative (GLI), for protection of aquatic life, human health and wildlife. When regulatory officials in the Great Lakes states initially reviewed the toxicological and bioaccumulation data, they noted the extremely low water concentrations that would have to be achieved to restore wildlife populations and to protect humans from an unacceptable risk of cancer.

Three questions were posed by the Science Advisory Board to the workshop participants.

1. Are the water quality criteria developed by the U.S. Environmental Protection Agency for protection of human health based on the cancer-causing ability of these chemicals, sufficiently stringent to protect the embryo and fetus from the developmental effects of persistent toxic substances, particularly neurological effects, the most sensitive endpoint?

2. Could restoration of the most sensitive wildlife populations be used as a surrogate for the achievement of human health protection?

3. Could the protection of human health and the restoration of wildlife be taken as indicators of the successful implementation of the Parties' policy on the virtual elimination of discharge of persistent toxic substances?

Water Quality Criteria for Protection of Human Health

At the workshop, independent presentations by senior scientists Dr. Milton Clark of the United States, and Dr. Deborah Rice of Canada showed a remarkable consistency in analyzing the available epidemiological and experimental studies concerning the neurological effects of PCBs. Neurological effects on humans are among the more sensitive endpoints for PCBs. The neurological findings in humans were supported by the results of the studies in monkeys, and the reference doses were similar. In addition, the water quality criteria derived from the cancer risk method, calculated as part of the Great Lakes Initiative, do seem to provide sufficient protection from neuro-behavioral and reproductive effects of PCBs and dioxins. The available environmental monitoring data indicate, however, that the present concentrations of PCBs in samples of Great Lakes water are about a hundred times higher than these criteria.

The board concludes that the water quality criteria for protecting humans from the carcinogenic effects of PCBs are adequate to protect developing infants from the neurological effects of prenatal exposures to PCBs.

The board concludes that, despite the significant improvements in water quality during the past two decades, there are still persistent toxic substances in fish and wildlife at concentrations that pose threats to human health and in some cases these concentrations are associated with actual effects on the more highly exposed individuals in critical subpopulations.

The SAB recommends the following.

- **The IJC challenge the Parties to demonstrate that their existing policies and programs, such as the Binational Toxic Substances Strategy, will be sufficient to achieve established water quality criteria.**

The Bald Eagle as an Indicator of the Restoration and Protection of Water Quality and of Human Health

The monitoring of trends in the exposures to, and effects of, persistent toxic substances in human populations remain a challenge for scientists involved in Great Lakes research. Not only are basin human populations mobile and their various routes of exposures to chemicals uncertain, but also much of their food is imported and therefore does not represent the contamination of their local environment. Thus, there is a need for the selection of indicators as surrogates of human exposures and effects. An indicator has been defined (International Joint Commission 1996) as something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable.

In the 1950s and 1960s, many of the North American populations of bald eagles were extirpated through exposures to persistent toxic substances (Sprunt et al. 1973). The population of bald eagles that nested in the shoreline habitat around the Great Lakes was among the most severely contaminated on the continent and the most seriously affected. Prohibitions on the use of DDT in the early1970s resulted in restoration of many North American populations, but only partial reestablishment in the Great Lakes basin. Bald eagles need adequate nesting habitat, sufficient food for themselves and their young and no human disturbance. While much of the shoreline of the Great Lakes basin provides these minimal requirements, large areas remain so contaminated with persistent toxic substances that bald eagles have been unable to reestablish territories. For example, the bald eagle population that existed on Lake Ontario was extirpated by 1958 and no eagles have attempted to reestablish territories despite the availability of many suitable locales. However, a pair of bald eagles that nested on Wellesley Island in the Saint Lawrence River, downstream from Lake Ontario, produced one chick in 1999. The bald eagle has been demonstrated to be particularly sensitive to certain organochlorine contaminants in the environment and therefore the board suggests that it would make a good indicator of the restoration of water quality.

Neurological effects on humans are among the more sensitive endpoints for PCBs. The neurological findings in humans were supported by the results of the studies in monkeys, and the reference doses were similar. In addition, the water quality criteria derived from the cancer risk method, calculated as part of the Great Lakes Initiative, do seem to provide sufficient protection from neuro-behavioral and reproductive effects of PCBs and dioxins.

The development of water quality criteria to restore the Great Lakes populations of bald eagles nesting in habitat along the shorelines has taken two different approaches: one empirical and the other experimental. The empirical dose-response relationship between contaminant concentrations and reproductive success is well documented and there are field measurements of the biomagnification factors, for certain persistent toxic substances such as PCBs, between water and bald eagle eggs that range from 25 millionfold to 100 millionfold. In the development of the water quality criteria for the Great Lakes Initiative, scientists have used data derived from experimental dose-response relationships and biomagnification factors. Using the protection of humans from the carcinogenic effects of PCBs, the criteria based on empirical data is ten times more stringent. Whereas the criterion based on experimental data is ten times less stringent than the human carcinogenesis criterion.

The board concludes that the restoration and normal reproduction of a Great Lakes population of shoreline nesting bald eagles might provide a useful surrogate for the protection of human health. There are, however, differences in the criteria derived from experimental versus empirical evidence, and further discussion is needed of which data should take precedence.

The population status and reproductive success of bald eagles can serve as an indicator of the Parties' progress under the Agreement on achievement of the restoration of water quality and on the adequacy of the water quality criteria. Though the bald eagle has been used as an unofficial indicator for monitoring regional trends in concentrations and effects of persistent toxic substances in the Great Lakes basin for more than 30 years, this usage is in jeopardy because the species is being removed from the U.S. national list of endangered species and therefore funding for monitoring is being sharply curtailed.

The SAB recommends the following.

- **The IJC endorse the bald eagle as an ecosystem indicator for the Agreement and recommend that the Parties commit funding to the long-term monitoring of the population status, trends in concentrations and effects of persistent toxic substances in Great Lakes bald eagles.**

A Biochemical Indicator of Exposure

The final workshop discussion focused on the need to find a biological indicator of exposure to specific compounds or classes of compounds with specific modes of action that are relevant to potential or observed harmful effects. There have been several proposals to use the Ah receptor in fish and wildlife species as long-term monitors of the trends in exposure of Great Lakes organisms to certain persistent toxic substances, such as the planar PCBs, polychlorinated dibenzo-*p*-dioxins and furans. Other candidate physiological markers include porphyrin accumulation and retinoid depletion in the liver, and some measure of immune function. Some monitoring data on these physiological endpoints are already available from studies on various species of fish-eating birds collected at various periods and from various sites around the Great Lakes.
While monitoring Ah activity in a species of fish-eating bird might be a valuable measure of exposure to compounds with this mode of action, there are also other modes of action of toxicological importance that need to be monitored. For example, there are certain non-planar PCBs that cause neurological effects through interfering with dopamine metabolism. Theoretically, a biochemical measure could be devised for monitoring the trends in exposures to substances with this mode of action. Finally, there is evidence from herring gulls and salmonids of the presence in the Great Lakes of unidentified anthropogenic or natural substances with goitrogenic activity. There is, thus, a need for a biological indicator of exposures to these compounds since thyroid functioning is such an important process, not only in the normal functioning of adult organisms, but also in the normal differentiation and development of embryos, fetuses and juveniles of all vertebrates.

The SAB recommends the following.

- **The IJC recommend that the Parties select biochemical indicators to monitor trends in exposures of fish, wildlife and human populations to compounds that interact with the aryl hydrocarbon (Ah) receptor, and fund research to develop biochemical assays to determine trends of chemically-induced changes acting through other mechanisms.**

1.4.2 Research and Regulatory Progress in Applying Toxic Equivalency Factors

The Agreement, in Annex 2, section 6(a) (i), states that Lakewide Management Plans ". . . shall include a definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combinations with another substance, including their contribution to the impairment of beneficial uses." In preparing Lakewide Management Plans, the interpretation of analyses of organochlorine chemicals in environmental and biological samples has been complicated by the number of residues present. One of the most toxic substances in many of the samples from the Great Lakes is 2,3,7,8-tetrachloro dibenzo-*p*-dioxin. Some congeners of polychlorinated biphenyls (PCBs), some other congeners of polychlorinated dibenzo-*p*-dioxins (PCDDs) and some of the polychlorinated dibenzofurans (PCDFs) have the same mode of action by binding to the aryl hydrocarbon receptor (Ah). Though all these congeners have the same mode of action, they have different potencies. The relative potency of each congener is known as the toxic equivalency factor (TEF). The interpretation of analytical data has been made easier by converting the results of the concentrations of each of the congeners using the TEFs to calculate the toxic equivalent concentrations (TEQs) as though all the dioxin-like activity were due to 2,3,7,8-tetrachloro dibenzo-*p*-dioxin. It has been assumed that the dioxin-like activity in terms of TEQs of each of the congeners is additive.

Originally, TEFs were developed based on the relative toxicity in mammals or in mammalian cell cultures. Thus, there was a need to rationalize the TEFs from the different data sources. Later work on fish and birds showed that TEFs for these organisms were different from those for mammals. Thus, there was again a need to rationalize the TEFs. TEFs can be used not only to interpret analytical data and to make cause-effect cases, but also can be used for risk assessment and for permitting discharges into the environment.

In the late 1980s, the U.S. Environmental Protection Agency initiated the U.S. Great Lakes Water Quality Guidance, to develop water quality criteria for the protection of wildlife from exposures to persistent toxic substances. Because approval of the guidance had implications for species listed as threatened, rare and endangered, the agency entered into formal consultation with the U.S. Fish and Wildlife Service (FWS) to comply with Section 7(a)2 of the Endangered Species Act. In the final biological opinion issued by the FWS, the two agencies agreed to hold a workshop to develop a consensus on the use of TEFs for chlorinated dioxin-like compounds, that would be protective of wildlife. This proposed workshop was merged with one that was being organized by the World Health Organization (WHO) in Stockholm, Sweden for June 15-18, 1997. At that meeting, experts developed tables of TEFs, through consensus, for mammals, fish and birds. This work has recently been published, after peer review, in the primary scientific literature (Van den Berg et al. 1998); see Table ?X? below. The U.S. EPA and the U.S. FWS held a workshop in Chicago, January 20-22, 1998, to address the use of TEFs in ecological risk assessments. These TEFs were then presented by Tim Kubiak at the IJC Workshop on Water Quality Criteria held in Chicago on March 25-26, 1998 and at the Meeting to Assess Scientific Issues in Relation to Lakewide Management Plans, held in Windsor on February 25-26, 1999.

Risk estimates for regulatory purposes have traditionally been based on total PCBs, because these were the only data available. The implications of using TEFs for each of the PCB, PCDD and PCDF congeners to calculate toxic equivalent concentrations (TEQs), are that the estimated risks are generally larger than when they were based on total PCBs. The current Great Lakes Water Quality Guidance for human health assessment includes TEFs for PCDDs and PCDFs to calculate a TEQ that establishes the risk for these substances. But PCBs are still assessed separately as total PCBs, even though TEFs are available. Similarly, for wildlife, criteria are set for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin, but not for other PCDDs and PCDFs; and criteria for PCBs are set on the basis of total PCBs and not on the basis of TEFs. Further, the current guidance does not address the subtle differences in the consensus WHO TEFs that were established for birds and mammals.

The Great Lakes Water Quality Guidance provides a process to derive water quality criteria for these compounds, but does not contain TEFs or total PCB criteria for fish, such as lake trout, and there is no guidance for integration of analytical data on PCBs, PCDDs and PCDFs across these families of chemicals. The current water quality criterion value of 14 ppt total PCB for protection of fish, is a carry-over from the EPA's *1986 Quality Criteria for Water* or *Gold Book*, and seems to be a default value. This criterion relies on dated toxicological and bioaccumulative potential rather than a consideration of the effects of dioxin-like compounds on early life stage mortality, which is the basis for the WHO TEF scheme for fish. If the reproductive, developmental and congener-specific bioaccumulation factors were taken into consideration, the water criteria for some individual congeners would be at least two orders of magnitude lower. A similar scenario unfolds for birds and mammals.

The application of the TEF/TEQ approach has several other regulatory implications. For example, fish and wildlife consumption advisories have been developed for humans based on total PCBs. Human health would be better protected if advisory decisions considered resulting total TEQs using the WHO TEFs, which take into account the risk posed by the most significant chlorinated compounds present with dioxin-like activity. The resulting total TEQ risk could then be compared side by side with total PCB risk.

The application of the TEF/TEQ approach has several other regulatory implications. For example, fish and wildlife consumption advisories have been developed for humans based on total PCBs. Human health would be better protected if advisory decisions considered resulting total TEQs using the WHO TEFs, which take into account the risk posed by the most significant chlorinated compounds present with dioxin-like activity.

This scheme using the TEF/TEQ approach successfully addresses the risks posed by substances that exhibit dioxin-like activity. But there are other PCBs that are toxic through other modes of action. These kinds of toxicity are not addressed through the TEF/TEQ scheme. Data sets relating to total PCBs have been used for risk assessment for effects that are not mediated through the Ah receptor. The TEF/TEQ approach should therefore be viewed as a complementary approach to, and not a substitute for, total PCB assessments.

The TEF/TEQ approach is geographically neutral and has universal utility for estimating dioxin-like activity in fish, wildlife and human populations exposed in all ecosystems throughout the world. The variables that are subject to change in risk assessments in other locations will be: target organisms; the complexity of their supporting food chains; water bioaccumulation factors or biota to sediment accumulation factors; and toxicity data that are relevant to protection and restoration of fish and wildlife populations. Regardless of geographic location, the critical pathway can be identified by using the WHO TEF/TEQ approach as the unifying methodology for assessing different target species and food-chains in different ecosystems.

The WHO TEF/TEQ approach is applicable to a variety of regulatory circumstances. For example, it can be used in the preparation of Lakewide Management Plans for critical pollutants and of Natural Resource Damage Assessments. Similarly, in tributaries to the Great Lakes that have limited water quality, the WHO TEF/TEQ approach can be used by the states or U.S. EPA under the U.S. Clean Water Act's section 303(d), to derive Total Maximum Daily Loads (TMDLs). After additional collection of supporting data on TEQs in waste loads from point and nonpoint sources, a TMDL may be established taking into consideration an allocation for an adequate margin of safety. When based on food chain

contamination, regardless of source, this could include contamination that arises directly from sediments or atmospheric deposition. To this end, U.S. EPA Region 5 is preparing a framework document, with the concurrence of the Agency's Science Advisory Board, on the application of the TEF/TEQ approach.

The Great Lakes Science Advisory Board concludes that the WHO TEF method would be a useful approach to determine additive effects of some critical pollutants related to Annex 2 of the Agreement.

The SAB recommends the following.

- **The IJC urge the Parties to implement the WHO toxic equivalency factors approach in the development of water quality criteria.**

Table 1 **World Health Organization Toxic Equivalency Factors (WHO TEFs) for Humans, Mammals, Fish and Birds. (With permission, from Van den Berg et al. 1998)**

	TEF					
Congener	Humans/Mammals		Fish	a	Birds	a
2,3,7,8-TCDD	1		1		1	
1,2,3,7,8-PeCDD	1		1		1	b
1,2,3,4,7,8-HxCDD	0.1	a	0.5		0.05	b
1,2,3,6,7,8-HxCDD	0.1	a	0.01		0.01	b
1,2,3,7,8,9-HxCDD	0.1	a	0.01	c	0.1	b
1,2,3,4,6,7,8-HpCDD	0.01		0.001		<0.001	f
OCDD	0.0001	a	<0.0001		0.0001	
2,3,7,8-TCDF	0.1		0.05		1	b
1,2,3,7,8-PeCDF	0.05		0.05		0.1	b
2,3,4,7,8-PeCDF	0.5		0.5		1	b
1,2,3,4,7,8-HxCDF	0.1		0.1		0.1	b,d
1,2,3,6,7,8-HxCDF	0.1		0.1	d	0.1	b,d
1,2,3,7,8,9-HxCDF	0.1	a	0.1	c,d	0.1	d
2,3,4,6,7,8-HxCDF	0.1	a	0.1	d,e	0.1	d
1,2,3,4,6,7,8-HpCDF	0.01	a	0.01	e	0.01	e
1,2,3,4,7,8,9-HpCDF	0.01	a	0.01	c,e	0.01	e
OCDF	0.0001	a	<0.0001	c,e	0.0001	e
3,4,4',5-TCB (81)	0.0001	a,c,d,e	0.0005		0.1	c
3,3',4,4'-TCB (77)	0.0001		0.0001		0.05	
3,3',4,4',5-PeCB (126)	0.1		0.005		0.1	
3,3',4,4',5,5'-HxCB (169)	0.01		0.00005		0.001	
2,3,3',4,4'-PeCB (105)	0.0001		<0.000005		0.0001	
2,3,4,4',5-PeCB (114)	0.0005	a,d,e,f	<0.000005	e	0.0001	g
2,3',4,4',5-PeCB (118)	0.0001		<0.000005		0.00001	
2',3,4,4',5-PeCB (123)	0.0001	a,d,f	<0.000005	e	0.00001	g
2,3,3',4,4',5-HxCB (156)	0.0005	d,e	<0.000005		0.0001	
2,3,3',4,4',5'-HxCB (157)	0.0005	d,e,f	<0.000005	d,e	0.0001	
2,3',4,4',5,5'-HxCB (167)	0.00001	a,f	<0.000005	e	0.00001	g
2,3,3',4,4',5,5'-HpCB (189)	0.0001	a,d	<0.000005		0.00001	g

Abbreviations: CDD, chlorinated dibenzo-*p*-dioxins; CDF, chlorinated dibenzofurans, CB, chlorinated biphenyls; QSAR,

a Limited data set.

b *In vivo* CYP1A induction after *in ovo* exposure.

c *In vitro* CYP1A induction.

d Prediction from quantitative structure-activity relationship based on CYP1A induction (monkey, pig, chicken, or fish).

e Structural Similarity.

f No new data from previous WHO review (Ahlborg et al. 1994).

g QSAR modelling prediction from class specific TEFs

1.5 REMEDIAL ACTION PLAN ASSESSMENT: SITE VISITS TO THREE AREAS OF CONCERN

The SAB held three of its regular meetings during the biennial cycle at Areas of Concern. This scheduling was intended to assist the Commission in assessing the status of progress in selected AOCs, in keeping with the practice of the SAB from 1995-97. Of the three locations, only St. Marys was designated by the IJC for status assessment in 1997-99, and, accordingly, the SAB coordinated its activities with a view to overall Commission needs and schedules. An IJC summary of this assessment is presented in its report, *St. Marys Area of Concern, IJC Status Assessment, February 1999.* The other locations, Cornwall and Grand Calumet, were identified in order to assist the Commission in considering their potential as status assessment candidates, because these areas had been visited by the SAB in the past, and because there was a strong local interest in hosting a board meeting to discuss pertinent scientific issues. Board comments and recommendations were forwarded to the Commission under separate cover as business arising from each of the meetings.

Such an assessment could serve to place the proposed Remedial Action Plans into the wider context of lakewide effects, and help the jurisdictions establish priorities for restoration and coordination. Overall, the SAB was encouraged by the progress of the Cornwall RAP and the integration of the St. Lawrence River Institute activities as part of their process.

Cornwall and Massena

The first of these meetings was the 107th meeting of the SAB held in Cornwall, Ontario at the St. Lawrence Institute of Environmental Sciences, on September 3 and 4, 1997.

It was recommended that:

- following receipt of the Stage 2 Cornwall Remedial Action Plan, that the Commission consider the Cornwall/Massena Areas of Concern for the purpose of a joint site assessment.

This recommendation was based on the benefits of obtaining a comprehensive assessment of progress from among the multi-jurisdictional efforts in the boundary waters. Such an assessment could serve to place the proposed Remedial Action Plans into the wider context of lakewide effects, and help the jurisdictions establish priorities for restoration and coordination. Overall, the SAB was encouraged by the progress of the Cornwall RAP and the integration of the St. Lawrence River Institute activities as part of their process.

St. Marys River

The second of these meetings was the 108th meeting of the SAB held in Sault Ste. Marie, Michigan on November 19 and 20, 1997. The board reached the following conclusions regarding the St. Marys River Area of Concern, based on the comments and submissions from its public meeting.

- **Inadequacy of the Planning Process**
  It was evident from the comments of the BPAC, citizens, elected officials and industry representatives that the protracted planning process was symptomatic of a general lack of leadership, support and resources from a lead agency. Several specific issues were noted in relation to this problem: the need for improved accountability to sustain progress; broadened BPAC membership to address plan implementation; local empowerment of stakeholders to define problems and assess options and possibly the use of a dispute resolution process to assist in the development of a partnership-based approach.

- **Scientific Needs**
  The SAB did not have the benefit of any integrated scientific analysis that either defined the problem(s) or supported any conclusions on the priorities for remediation. Health issues have not been addressed, particularly in relation to the known effects caused by exposure from persistent toxic substances to fish, wildlife and humans. The high level of knowledge and GIS capability with respect to sea lamprey, including remedial least-cost analysis, contrasted sharply with the inability to address other use impairments confidently. The Department of Fisheries and Ocean's approach on sea lamprey was viewed as a model that could be extended to the entire RAP.

- **Existing Sources**
  The SAB was impressed by the efforts made by the industries in recent years to reduce pollutant discharges to the river. Significant improvements have been made by both St. Marys Paper and Algoma Steel since 1990, and the board concluded that these actions will have important positive consequences for river water and sediment quality. Representatives from both companies expressed an interest in the problem of contaminated sediments and a willingness to work with the other stakeholders in planning and executing appropriate remedial measures. It was evident that both industries have focused to date on compliance

with regulatory requirements related to pollution control rather than undertaking a comprehensive assessment of their roles or responsibilities in larger remedial efforts.

- **Other Comments**
  Communication was identified by stakeholders as generally inadequate. Several examples included a lack of community knowledge about the recent sampling activities of various agencies and about the potential for drinking water impairment downstream of the primary sewage treatment plant discharge. There was concern that the Area of Concern designation might compromise efforts to obtain national recognition of the river as a heritage site, rather than an appreciation that remedial actions could sustain and complement the restoration and protection of natural attributes.

  It was apparent to the SAB that the benefits of increased community awareness and educational opportunities that often characterize successful RAPs have not occurred in the St. Marys RAP. With strengthened communication, such as school programs, community cleanup activities, and an improved media focus, the planning process could be greatly facilitated.

Grand Calumet

The third of these meetings was the 111th meeting of the SAB held at the Spring House Inn, Porter, Indiana, on September 24, 1998. It was concluded that:

- the Grand Calumet Area of Concern would benefit from a comprehensive review by the IJC under its Annex 2 status assessment process. The area is a unique combination of serious pollution problems, significant natural heritage and community development challenges. On the basis of the relevance of sediment remediation to Remedial Action Plans, the SAB identified there is a considerable wealth of experience and knowledge in addressing issues related to the management of contaminated sediment by the U.S. Army Corps of Engineers, U.S. Steel and the Grand Cal Task Force, that could be transferred throughout the basin with the involvement of the Commission.

It appeared from the presentations and discussions with two of the major industries in the area, U.S. Steel and Bethlehem Steel, that industry has made a renewed commitment to environmental management and stewardship. The U.S. Steel project, to remove contaminated sediments in five miles of the Grand Calumet River, is one of the largest projects of its kind in North America and represents state-of-the-art engineering and technology.

The ecological research efforts and capacity at the Lake Michigan Ecological Research Station and the Great Lakes Science Center continue the standard of excellence in the tradition of Dr. Henry Cowles, one of the area's earliest and most eminent researchers. While the current focus of the research has been on natural history, conservation and protection of remnant natural heritage areas, an opportunity was identified by the SAB to extend this research to include restoration ecology with a view to integrating the recovery at remedial and industrial sites into the surrounding natural landscape. Such an initiative could be facilitated through the RAP with enhanced interagency coordination.

The Grand Calumet Area of Concern would benefit from a comprehensive review by the IJC under its Annex 2 status assessment process. The area is a unique combination of serious pollution problems, significant natural heritage and community development challenges.

Based on the experience of planning advisory committees elsewhere in the basin, there are strategic advantages for the agencies to encourage further local involvement in the CARE (Citizens' Advisory for Remediation of the Environment) committee, particularly in supporting local leadership as the committee chair. Notwithstanding the known practical benefits of encouraging public involvement in plan preparation, public support in decision making is a key factor to plan implementation and ultimate progress.

Academic institutions in the community, such as Purdue University and Indiana University, provide opportunities to diffuse and apply academic research to problems in the area through local partnerships and initiatives. This is an example of outreach that could be further promoted in discussions between RAP developers and local leadership. University involvement in RAPs is an approach that has been used successfully elsewhere in the Great Lakes basin as a resource for addressing community needs.

In conclusion, the SAB commends the use of status assessments as an interim review process in specific instances where RAP progress has been slow. The SAB experience in supporting these reviews, by assessing scientific issues and facilitating stakeholder dialogue through site visits, invited scientific presentations and public meetings is viewed by the board as an effective approach to provide scientific advice to the Commission with respect to Annex 2 progress. The SAB urges the Commission to continue these efforts and intends to coordinate its future public meetings in the 1999-2001 biennial cycle in order to continue to contribute a scientific perspective to the status assessments.

1.6 TOLEDO NONPOINT WORKSHOP: NONPOINT SOURCES OF POLLUTION TO THE GREAT LAKES BASIN

Background

1998 marked the 20th anniversary of the publication of the final reports of the Commission's Pollution From Land-use Activities Reference Group (PLUARG). PLUARG produced a body of work that remains the cornerstone of current thinking about nonpoint source pollution in the Great Lakes and elsewhere. Now, 20 years after PLUARG, the Workgroup on Parties Implementation seeks to assess the status of nonpoint source pollution control in the Great Lakes basin, particularly progress by the Parties under Annexes 3 (Control of Phosphorus) and 13 (Pollution from Non Point Sources) of the Agreement. To that end, the workgroup sponsored a special session at the Great Lakes soil erosion and sediment control conference, held in Toledo, Ohio, September 16-18, 1998. The following report summarizes the findings of that session.

Session Format

The workgroup commissioned two major papers from leading experts in urban and agricultural nonpoint source pollution control. The first of these was from Mr. Tom Schueler, Executive Director of the Center for Watershed Protection, Washington, D.C., on the topic of *Source and Controls of Pollutants in Urban Runoff.* The second was from Professor Terry Logan, a member of the Environmental Sciences faculty at Ohio State University and a former PLUARG participant. Dr. Logan spoke on the topic *Nonpoint Sources of Pollutants to the Great Lakes - 20 Years Post PLUARG.*

In addition to these two speakers, the session included a panel of four experts: Dr. Trevor Dickinson, Emeritus Professor of Water Resources Engineering, University of Guelph, and a former PLUARG participant; Dr. Roger Brook, Professor of Agricultural Engineering, Michigan State University; Mr. Michael Hunter, Certified Crop Adviser, Bruce AgVise, Ontario; and Mr. Peter Johnson, Soil and Crop Advisor, Ontario Ministry of Agriculture and Food.

The session was attended by about 25 participants, and the breadth of experience within this group contributed markedly to the lively technical discussion during and following the formal presentations.

Requirements Under Agreement

Two annexes of the Agreement are relevant to the control of nonpoint sources of pollution. Annex 3 provides several key provisions relating to the control of phosphorus, including load reduction targets. Annex 13 of the Agreement, on Pollution from Nonpoint Sources, calls for the Parties to:

- identify land-based activities contributing to water quality problems described in Remedial Action Plans for Areas of Concern or in Lakewide Management Plans, including but not limited to phosphorus and critical pollutants; and
- develop and implement watershed management plans, consistent with the objectives and schedules for individual Remedial Action Plans or Lakewide Management Plans, on priority hydrologic units to reduce nonpoint source inputs.

Annex 13 specifies a number of other requirements relating to the control of nonpoint sources, including surveillance, surveys and demonstration projects. Furthermore, Annex 13 emphasizes the importance of demonstration projects of remedial programs on pilot urban and rural watersheds to advance knowledge and enhance information and education services, including extension services, where applicable.

Nevertheless, it became apparent during the workshop that nonpoint sources of pollution to the Great Lakes basin remain a serious issue, and that phosphorus levels are far from under control.

Progress to Date

It was pointed out at the session that progress in these areas was significant through the 1980s but has flagged over the past decade. In part, this may be because other issues, such as concern for persistent toxic organics, became prominent in the environmental agenda and eventually took precedence over issues that were generally believed to have been solved. Nevertheless, it became apparent during the workshop that nonpoint sources of pollution to the Great Lakes basin remain a serious issue, and that phosphorus levels are far from under control. Phosphorus continues to be a major source of concern in the Great Lakes basin, both because of persistent eutrophication in some areas and because control strategies have been less effective than anticipated. Similarly, soil erosion (leading to high sediment loadings to watercourses) remains a significant problem in some areas.

In view of the fact that nonpoint sources of pollution are significant in a number of Areas of Concern, and therefore that remedial actions in those areas remain to be developed, the findings of this session also have important implications for the

management of Areas of Concern and for Lakewide Management Plans.

The SAB recommends the following.

- **The IJC identify to the Parties the need for continued action and vigilance in the control of pollution from nonpoint sources. Such action will be particularly urgent in Areas of Concern where nonpoint sources have been a major contributor to the impairment of beneficial water uses.**

- **The IJC begin discussions with the Parties to review the adequacy of the phosphorus load reduction targets described in Annex 3 (Control of Phosphorus) of the Agreement, because phosphorous continues to be a concern in the lower lakes.**

Participants at the session also noted the tremendous changes that have occurred in the Great Lakes basin over the past 20 years, observing that the basin of today is significantly different from the basin of 20 years ago. These fundamental changes in the basin may be far more important than the presence or absence of controls in influencing pollution levels. Urbanization in particular has brought significant changes to natural systems, particularly in increased land surface imperviousness. These changes have in turn led to increased runoff and associated water-quality impairment. The impacts of this urban drainage on receiving waters are significant and must be included in any attempt to address nonpoint source pollution. Major improvements in urban drainage impacts may be achievable through modest land-use planning changes coupled with appropriate and well-maintained structural measures such as infiltration trenches and storm-water retention ponds. Jurisdictional issues may, however, be thorny, because effective control of urban nonpoint sources demands linkages between environmental and planning agencies at several levels of government. These linkages may be entirely absent or complicated by local political or economic forces. In urban systems, the appropriate planning unit may be much smaller than in a largely permeable agricultural watershed. Urban management systems may have to be based on sewersheds — the areas served by individual sewer systems — rather than on natural drainage patterns.

In rural areas, economic forces on agriculture have forced a move toward intensive farming, often in large-scale operations quite different from the traditional family farm. Two effects have arisen from this move. First, livestock operations have tended to move toward confined animal feeding operations, which produce large volumes of manure and related waste waters, such as wash waters. If not properly managed, these concentrated waste sources can have a dramatic impact on local receiving waters. A second influence in agricultural portions of the basin has been the gradual implementation of soil conservation practices, such as conservation tillage or no-till, throughout the basin. Some regions have embraced these practices more enthusiastically than others. Several participants noted that, because of high local acceptance, or topographic, soil or crop factors, we appear to be approaching the limits of acceptance and/or effectiveness of available soil conservation technology in some areas. These comments underscored the need for local measures tailored to local needs throughout the basin. Conservation tillage clearly remains a powerful tool in some parts of the basin, but where it has been fully implemented and nonpoint source pollution remains a problem, other measures, for instance advanced treatment systems, may be appropriate.

In both urban and rural systems, microorganisms emerged as an issue of particular concern, especially following recent outbreaks of *Cryptosporidium* that may have arisen from animal wastes. The full range of microbiological pathogens, their biology and pathways, and appropriate control/treatment methods are still largely unknown, but are likely to be important avenues for future investigation. The urgency of this issue has increased in recent years because of drinking water impairments at several locations in the Great Lakes basin, revealing inadequate protection, control and treatment capabilities.

The SAB recommends the following.

- **The IJC initiate discussions with its advisory boards and the Parties about the significance, sources, biology and pathways of microorganisms arising from nonpoint sources of pollution.**

In contrast to rising concern about pathogens, pesticide use was viewed by participants as much less problematic than it was even a decade ago, in part because of the advent of new products with very short half-lives and low persistence, also because of improved pesticide storage, handling and user training programs.

Urbanization in particular has brought significant changes to natural systems, particularly in increased land surface imperviousness.

In addition to known and emerging pollutant sources, participants raised the issue of uncertainties in climate change and weather patterns, and their potential to impact the distribution and abundance of water resources. New technologies, such as precision agriculture (discussed below), may help us do the right thing at the right time in responding to climate and weather change, but only if those technologies are economically feasible, understood and used by farm operators.

Although we now have much better general information about the nature and importance of sources, most of this information is derived from inference and not from direct measurement. In fact, we have few direct measurements of loads, especially the detailed chemistry (for instance of phosphorus species) that may be relevant in assessing the effectiveness of proposed controls. As governments scale down their monitoring and surveillance efforts, these data are becoming scarcer and older. Without strong data, we lack proof of cause and effect relationships, and therefore cannot make sound management decisions with confidence. Computer models of agricultural systems, for instance, too often rely on inadequate data to make predictions that are influential in guiding (possibly erroneous) management decisions. The paucity of good data on nonpoint source loads and their impacts on environmental decisions has contributed to confusion about appropriate actions and endpoints and is a major obstacle to further progress on commitments under the Agreement.

The SAB recommends the following.

- **The IJC urge the Parties to ensure that there are adequate monitoring and surveillance programs for nonpoint sources of pollution, particularly for the evaluation of the effectiveness of specific management actions, for the identification of cause-and-effect relationships and for informed decision making about the control of nonpoint sources.**

Emerging Technologies

Comments from panelists and participants alike indicated that we are now reasonably well informed about the general characteristics of sources, with the notable exception of micro-organisms, and the limits of control technologies. Many of the actions recommended for phosphorus control under Annex 3 have been implemented throughout the basin. We appear to be approaching the limits of acceptance and/or effectiveness of available soil conservation technology in some regions where nonpoint source pollution is still not adequately controlled. In these areas, more aggressive measures, for instance using emerging technologies drawn from industrial and municipal systems, may be necessary. In all cases, measures must be planned and managed on a local basis, in response to the needs of the local system. The Level 1 and Level 2 actions identified in Annex 3 apparently are not, in themselves, any longer sufficient for the control of nonpoint sources. Instead, it will be necessary to develop new technologies and to couple those new approaches with existing methods and improved land-use planning.

Emerging technologies for control of nonpoint source pollution generally take two forms: modification of technologies in use in other industrial or municipal sectors; and optimization of nutrient and soil management through new microprocessor technologies. Control at source was considered by participants to be critical. It is, however, clear that we cannot rely on existing technologies, however well implemented and maintained, to resolve the nutrient and sediment loads arising from nonpoint sources of pollution. Both in the urban and in the rural environment, future progress must depend on a combination of technology and land-use planning on a watershed or subwatershed basis. It is likely that farmers will need financial incentives to risk new technologies or lower fertilizer and pesticide inputs. In some areas (for example, precision agriculture), technology development may be proceeding faster than our ability to implement it effectively. It is unlikely that the agricultural community will be able to fund the necessary education, economic incentive programs and agronomic research. This is an area where government support could be instrumental in helping this technology to reach its full potential.

The IJC urge the Parties to place special emphasis on urbanizing areas; that is, those areas in transition from rural to urban uses. Such land-use changes represent opportunities for implementation of watershed management plans as defined under Annex 13, 2(b), as a condition of their development.

Although government regulation has been an effective tool for the control of industrial and municipal point sources, it has been less effective in managing nonpoint source pollution, in part because of the diffuse nature of sources and the problem of assigning ownership. Traditionally, farmers have enjoyed the right to farm, with associated exemptions from many controls that would apply in other sectors. Farm operators are therefore likely to resist government regulation strenuously, arguing that controls must be on a site-by-site basis and developed in the context of local economic and environmental conditions. Economic incentives and education/extension programs have been and are likely to continue to be critical in encouraging progress in control of agricultural nonpoint sources.

The SAB recommends the following.

- **The IJC request the Parties to increase funding for research and development of new technologies and techniques for the control of urban and rural nonpoint sources of pollution.**

- **The IJC urge the Parties to place special emphasis on urbanizing areas; that is, those areas in transition from rural to urban uses. Such land-use changes represent opportunities for implementation of watershed management plans as defined under Annex 13, 2(b), as a condition of their development.**

In the view of the Science Advisory Board, the Commission has an important and central role to play in alerting the Parties and individual Great Lakes jurisdictions to the need for continued action on phosphorus, sediment and pathogen control. It is clear that obligations under Annex 13 of the Agreement cannot be met with the present level of effort. New technologies combined with improved land-use planning will be necessary to meet targets and continue the progress achieved to date.

The SAB recommends the following.

The IJC request the Parties to report on their implementation of the recommendations for agricultural practices that were published in its Ninth Biennial Report on Great Lakes Water Quality.

1.7 WATCHING BRIEF ON ENDOCRINE DISRUPTORS

The Commission directed the Great Lakes Science Advisory Board, in its December 1997 memorandum concerning Priorities for 1997-1999, to keep a watching brief on the issue of endocrine disruptors. A watching brief is intended to update the Commission on the most recent developments occurring with respect to an issue relevant to Great Lakes research or policy. Governments have reviewed the evidence concerning endocrine disruptors (United States Environmental Protection Agency 1997; Health Canada 1998) and described their research programs (Reiter et al. 1998). In 1996 the U.S. Congress amended the Food Quality Protection Act and the Safe Drinking Water Act to require the U.S. EPA to establish a screening program to determine which pesticides and other substances might have effects on human endocrine systems. The U.S. EPA set up the Endocrine Disruptors Screening and Testing Advisory Committee (EDSTAC) that met over the following two years and reported in September 1998. U.S. EPA published its proposed endocrine disruptors and screening program, largely based on the EDSTAC report in December 1998 in the Federal Register. In Europe, the European Commission set up a Working Group on Endocrine Disrupters under the Scientific Committee on Toxicity, Ecotoxicity and the Environment (1999) that concluded that existing guidelines for toxicology testing were not able to detect all endocrine disruptors and recommended enhanced or new testing guidelines. Through the Environment Directorate of the Organization for Economic Cooperation and Development (1997), an appraisal has been undertaken of test methods for detecting chemicals that disrupt sex-hormones and a survey conducted of the regulatory activities in member countries. Similarly, the Japan Chemical Industry Association (1997) undertook a review, on a global basis, of the scientific and regulatory strategies for chemicals that mimic hormones and put forward proposals for research, including international cooperation.

The SAB has reported extensively on this issue over the past 10 years in its reports to the Commission. During the decade, the various investigations about the effects of persistent toxic substances in the Great Lakes on human health have been continually reviewed, integrated and published in the scientific literature and disseminated in more accessible documents for the public (Johnston et al. 1998). There is, however, a convergence of the various pieces of scientific evidence, and this convergence supports a conclusion of the widespread occurrence of chemicals that interfere with the endocrine system and of the associated effects. These pieces of scientific evidence include the striking consistency between the epidemiological evidence and the experimental studies undertaken to investigate toxicity and mechanisms of action. In addition, exposure of human and wildlife populations to chemicals that interfere with the endocrine system has lead to reproductive and developmental effects. The issue of chemicals in the Great Lakes frequently relates to various aspects of endocrine disruption and can be addressed as three central questions.

1. What constitutes an adverse effect?
2. What are the implications of irreversible effects at low doses?
3. How are mixtures of substances to be tested?

What Constitutes an Adverse Effect?

In the early 1980s, a cohort of infants was established in western Michigan to investigate the effects of maternal consumption of Lake Michigan fish prior to and during pregnancy (Jacobson et al. 1984). Subsequent testing showed deficits in memory (Jacobson et al. 1985) and cognition (Jacobson and Jacobson 1993, 1996). Ten years later, a second cohort was established at Oswego, in upper New York state, to replicate the original study with infants whose mothers had eaten Lake Ontario fish (Lonky et al. 1996). These findings are consistent with studies on other developmental neurotoxicants with similar or other modes of action. For example, it is well established that children who are exposed to lead, either from gasoline or from paint, suffer a loss of I.Q. points, and there is a well-established dose-response relationship between the amount of lead in the blood and these deficits in the development of intelligence (Agency for Toxic Substances and Disease Registry 1988; Centers for Disease Control 1991). A child who is moderately exposed to lead will not show signs of disease that could be diagnosed, but may suffer an irreversible loss of development of normative functioning, such as is measured by I.Q. (Needleman and Gatsonis 1990).

These several studies show that infants and children who are more highly exposed to pollutants, particularly from maternal consumption of fish prior to and during pregnancy, have suffered loss of cognitive development. More recent evidence indicates that there are other normative functions that are affected by exposures to pollutants and that would not be diagnosed using the disease model of medicine. These normative functions include memory, emotion, response to frustration and decision making. There is a need for a methodology for assessing the effects of endocrine disruptors on community health, as recommended in the section on The Definition of The Threat to Human Health.

There is no doubt, based on the Great Lakes monitoring data, that the levels of persistent toxic substances have declined in the past 30 years (Pekarik and Weseloh 1998). However, there has been an increasing knowledge of the dangers posed by exposures to these substances. There have been questions posed as to whether the risks from persistent toxic substances in the Great Lakes are higher than elsewhere. There is now a much better understanding of the subtle effects on the endocrine system, neurological development and functioning (Colborn et al.

1998), and the development of the immune system (Voccia et al. 1999) from low level exposures to a range of chemicals. The replication of the findings from the Michigan cohort in the studies of the Oswego cohort underscores the robust nature of this association. The findings of other behavioural sequelae in the more highly exposed infants from the Oswego cohort reemphasize the significance of these exposures for those involved in human health protection. In addition, there are indications that these biologically significant effects could occur in human populations at levels of exposure close to background (Johnson and De Rosa 1999).

There is considerable evidence for the effects of critical pollutants on human reproduction at existing concentrations in the Great Lakes. In one study being undertaken in New York state, there is a significant reduction in the timing of the menstrual cycle in women who consumed more than one meal per month of contaminated fish from Lake Ontario (Mendola et al. 1997). In another study (Courval et al. 1999), which is being undertaken in Michigan, about 15 percent of 625 married couples, who were trying to conceive for at least 12 months, were unsuccessful. It seems that the strongest association is found between the increase in the rate of conception failure in these couples and the fish consumption by the men. Though both men and women consume Great Lakes fish for most of their reproductive years, men tend to consume much more fish than women.

There are several substances in the Great Lakes that interfere with the development of the immune system in exposed organisms, including humans (Weisglas-Kuperus et al. 1995), resulting in greater susceptibility to bacterial and viral infections and to cancer, as well as inducing abnormal immune responses, such as hypersensitive reactions, including allergies and autoimmune diseases. While most research on immunocompetence has been undertaken on gulls, terns, seals, polar bear, beluga whales and osprey, the focus is now on populations that are heavily dependent on wild fish and game for cultural and economic uses and for sport.

There is evidence of auditory impairment in Inuit children in the Arctic exposed to contaminants from consumption of wild foods (Julien et al. 1987). Similarly, from laboratory experimentation with rats exposed to high doses of Arochlor 1254, there is evidence of auditory loss (Goldey et al. 1995). Several species of organisms, such as whales, use low frequency sound for communication and echo-location. From laboratory experiments with rats, researchers have established that the mechanism of action of this auditory loss is through the PCBs causing a decrease in the circulating levels of thyroxine (hypothyroxinemia). The same effect can be induced with propylthiouracil that interferes with thyroxine production, and can be reversed by feeding thyroid hormone. During the EDSTAC meetings, there were questions about the specific mechanism, within the thyroid economy, that lead to this hearing loss. There are twelve known ways that chemicals can interfere with thyroid production, transport, transformation, metabolism and excretion. This instance poses the question of the level of specificity required for decision making to protect the public good.

This particular instance demonstrates the serious difficulties for regulatory officials in deciding when there is enough information to prohibit the manufacture, distribution, use, sale and disposal of a chemical or when to undertake preventive and remedial action. For example, during the EDSTAC meetings, there was extensive discussion of the definition of endocrine disruptors and particularly of what constituted an adverse effect. The evidence from the Jacobsons' research (Jacobson and Jacobson 1996) of a loss of 6.2 I.Q. points indicates that the result of the exposure of the infants was a deficit in cognitive function. However, it has been argued that the loss of 6.2 I.Q. points is within two standard deviations of the norm and therefore the deficit cannot be described as an adverse health effect. The question posed by this conclusion is whether this definition of an adverse effect is adequate to protect the public good from the effects of endocrine disruptors (Colborn and Clements 1992; Colborn et al. 1998, 1999; Johnson et al. 1998; De Rosa et al. 1999).

There is considerable evidence for the effects of critical pollutants on human reproduction at existing concentrations in the Great Lakes. In one study being undertaken in New York state, there is a significant reduction in the timing of the menstrual cycle in women who consumed more than one meal per month of contaminated fish from Lake Ontario (Mendola et al. 1997). In another study (Courval et al. 1999), which is being undertaken in Michigan, about 15 percent of 625 married couples, who were trying to conceive for at least 12 months, were unsuccessful. It seems that the strongest association is found between the increase in the rate of conception failure in these couples and the fish consumption by the men.

Irreversible Effects at Low Doses and Some Limitations of Testing

Much of the evidence cited above is from epidemiological research undertaken decades after the substances have been released to the Great Lakes and after exposures of toxicological significance have been shown retrospectively to have occurred. In preventive rather than restoration terms, experimental toxicology is the approach used to warn of the potential dangers posed by chemicals. It is only after chemicals have been released and have caused damage that epidemiology can be used. During the EDSTAC discussions, the participants addressed recent evidence that has shown the limitations of experimental

toxicology, undertaken at high doses, in protecting human health, particularly from chemicals that disrupt the endocrine system. Traditionally, when chemicals were tested for their toxicity, high doses were administered to laboratory animals and the frequency of health endpoints such as cancer, mutations, birth defects and obvious neurotoxicity were determined in the exposed animals.

Concern has shifted to endpoints that are more cryptic; measured as shifts in development of the functioning of the endocrine system resulting in altered sex steroids and changes in thyroid economy, and in the functioning of the reproductive, nervous and immune systems (Colborn et al. 1998, 1999). These changes can undermine an individual's potential, and they occur at very low doses (Welshons et al. 1999) but they neither shorten the life of the test organism nor produce the traditional endpoints of concern. Evidence now exists that a number of the contaminants found in the Great Lakes fit into the latter category. First, there appears to be no threshold at which they do not effect a change. Second, the physiological effects are manifested at very low doses that in the past were considered safe, but that are at concentrations that occur in the environment. And third, depending on time of exposure, the effects at these low doses are expressed in a non-linear, dose-response manner in that they produce an inverted U-shaped curve in which effects appear at low doses that do not appear at high doses (vom Saal et al. 1995; Welshons et al. 1999). From a mechanistic standpoint, at the high doses, the feedback to the brain shuts down the receptors so that there is no longer an effect.

EDSTAC recommended testing for estrogenic/anti-estrogenic, androgenic/anti-androgenic and thyroid activity. Recent publication of the papers from the work session on health effects of contemporary-use pesticides in the *Journal of Toxicology and Industrial Health* underscores the difficulty of undertaking this kind of research and testing. For example, methoxychlor, which is a substitute for DDT, causes enlargement of the prostate gland as though methoxychlor were an estrogen (Gray et al. 1999). In contrast, a series of assays for anti-androgenic activity has been performed with several new fungicides, plasticizers and some old insecticides, including methoxychlor, DDT and its metabolite DDE. In this assay, methoxychlor acted as an anti-androgen and blocked the androgen receptors in the developing male animal so that it did not develop like a male. These are the kinds of problems that have been occurring in vertebrates in the Great Lakes, and that have not yet been successfully investigated and remedied. While short-term assays for screening chemicals for estrogenic/anti-estrogenic, androgenic/anti-androgenic and thyroid activity are useful and economical, the endocrine system is much more complex than represented by these biochemical assays and there is a need to test chemicals using an embryo assay to test for a wide range of endocrine effects.

Testing of Mixtures of Substances

Recent evidence has been published showing that the mixtures of a pesticide, a herbicide and a fertilizer exhibit interactive effects on the endocrine, immune and behavioral systems (Porter et al. 1999). These effects suggested to the authors that there were deficiencies in testing requirements for pesticide registration and associated implications for human health of present trends in pesticide use. The situation is further complicated by the recent discovery that components of plastics that have been manufactured and used in increasing quantities since the Second World War, have now been shown to be endocrine disruptors. While it is clearly impossible to examine all possible mixtures of chemicals experimentally (Carpenter et al. 1998), it may be practical to test mixtures of chemicals that are likely to be associated with each other from specific activities such as crop rotation or tillage practices, or effluent discharges for their interactive threats to human health.

1.8 EMERGING ISSUES

1.8.1 Aboriginal People

We give thanks to the spirit of the waters for our strength of well being. The waters of the world have provided to many; they quench thirst; provide food for plants and are the source of strength for many medicines we need. Once acknowledged, this too becomes a great power for those who seek this gift, for humans themselves are made of water. Now our minds are one, agreed.

Okenten Karithwatehk-wen
(in Benedict 1985)

The United States has a unique legal relationship with Indian Tribal governments as set forth in the Constitution of the United States, treaties, statutes, executive orders and court decisions. Since the formation of the union, the United States has recognized Indian tribes as domestic dependent nations under its protection. In treaties, our nation has guaranteed the right of Indian tribes to a self-government.

U.S. Executive Order 13084
Presidential Document May 14, 1998

These communities are the repositories of vast accumulations of traditional knowledge and experience that link humanity with its ancient origins. The starting point for a just and humane policy for such groups is the recognition and protection of their traditional right to the land and other resources that sustain their way of life-rights they may define in terms that do not fit into standard legal systems.

Our Common Future
World Commission on Environment and Development 1987

Since the signing of the 1972 Agreement, the Commission has received numerous submissions, concerning Great Lakes matters, from aboriginal people living in the Great Lakes basin, as well as from First Nation, Indian Tribal governments and their organizations or institutions (Abbott, February 1998 unpublished report). During 1995-97, the IJC undertook four community consultations at Walpole Island, Akwesasne in Wisconsin and Michigan. In addition, aboriginal scientists from both countries have served and continue to serve on the Science Advisory Board (SAB) or its workgroups and on the Council of Great Lakes Research Managers, and are often invited to participate as scientific experts at SAB-sponsored activities supported by the Commission. The Mohawk Council of Akwesasne has hosted two SAB meetings, most recently the 107th meeting of the SAB held September 3-4, 1997 at the St. Lawrence Institute of Environmental Sciences in Cornwall, Ontario.

On the occasion of the Science Advisory Board's 112th meeting, its Workgroup on Emerging Issues met with representatives and advisers of aboriginal organizations from both the United States and Canada. These included the U.S. Great Lakes Indian Fish and Wildlife Commission, the Anishnabek Ontario Fisheries Resource Centre, the Walpole Island First Nations Heritage Centre and the Union of Ontario Indians. Policy advisers from the U.S. Environmental Protection Agency and Environment Canada were also present. The purpose of this meeting was to identify scientific issues affecting aboriginal uses of the Great Lakes and to identify how these could be addressed in terms of water-quality management and decision making under the Agreement. Two central issues emerged from the discussion: The values and uses of traditional knowledge and the involvement of First Nation, Indian and Tribal governments as governments with the Parties to the Agreement.

Traditional Ecological Knowledge

Aboriginal people in the Great Lakes basin have knowledge that is vital to the understanding of the Great Lakes ecosystems. Aboriginal people participate in Commission activities because of their personal and professional expertise. Their knowledge of their communities and areas also has proved to be very useful to the Commission and its boards. The board considers traditional ecological knowledge as an opportunity to enhance and complement traditional research methodologies and data sources.

In the Great Lakes, aboriginal people live on all of the most important water ways and interconnecting channels, as they have done for thousands of years. Their knowledge is important for understanding how these areas function. Traditional ecological knowledge available in aboriginal communities is being increasingly incorporated by academics and government agencies to complement traditional approaches to scientific discovery.

Traditional ecological knowledge contributes to scientific understanding in several unique and important ways. It often comprises the only historic record of the state of the Great Lakes prior to the extensive human settlement and development over the last two centuries. This knowledge offers a unique perspective in understanding the changes that have occurred in the basin ecosystem and the goals needed to achieve its restoration. Aboriginal people view nature as an interconnected web of life that includes humans, and therefore their culture is based on an extensive knowledge of the ecosystem upon which their survival and spiritual values historically depended. Such knowledge and experience now are critical to understanding the Great Lakes basin ecosystem. Finally, the understanding of impaired use by aboriginal people, because of cultural differences, differs from that of other groups. For example, aboriginal people may consume all edible parts of fish and wildlife, including the liver. Discernment of tainting of fish and wildlife flavour would differ for groups that consume muscle tissue only. Similarly, the assessment of degraded fish and wildlife populations could differ from the needs and historic use of natural stocks by aboriginal communities.

This unique perspective of aboriginal people is recognized by non-governmental organizations in the Great Lakes. Groups like the Sierra Club, Greenpeace and Great Lakes United are appointing aboriginal members to their boards and committees to assist these organizations to a more cooperative partnership with other Great Lakes residents. The Great Lakes Indian Fish and Wildlife Commission, over the years, has proven that it can work successfully with other organizations toward improved fish and wildlife management. The St. Lawrence River Institute of Environmental Science works in cooperation with the Mohawk Community of Akwesasne, the City of Cornwall and local industries to research and educate people about river environmental problems and their remediation. These groups are seeking to understand and acknowledge aboriginal interests in the Great Lakes, and are working to avoid any confrontation or conflict that might arise through misunderstanding.

Similarly, the role of the Commission to assess the Parties' progress under the Agreement, is enhanced by including traditional ecological knowledge. With the establishment of watershed boards for other boundary waters than the Great Lakes, the involvement of First Nation, Indian and Tribal governments becomes even more important. All of the boundary waters have associated aboriginal communities that rely upon water resources. Federal, provincial and state governments often fail to comprehend the impacts of their water policies on aboriginal people. Legal remedies and recent court cases have affirmed the rights and responsibilities of aboriginal people under Treaties, to the uses of and interest in the water, lands and resources of these areas.

The SAB recommends the following.

- **The IJC advise the Parties of the importance of traditional ecological knowledge for understanding the Great Lakes basin ecosystem, and the need to develop mechanisms and processes to ensure that the opportunity to contribute such knowledge is fully provided to aboriginal people and their structures of governance.**

Further Indian and Tribal Governmental Involvement

In keeping with the use of traditional ecological knowledge to enhance and complement understanding of the Great Lakes basin ecosystem, it was clear from the representatives at the

November 1998 meeting of the Workgroup on Emerging Issues that aboriginal interests related to the purpose of the Agreement are particularly significant in terms of the many small communities throughout the Great Lakes region and the extent of commercial and subsistence fishery activities that are affected by water quality concerns, especially related to human health. It also was noted that as governments, aboriginal and tribal leaders have limited direct opportunities to influence lake management decisions being made by other levels of government, even when they are directly affected by the decisions. Examples of several of these concerns include habitat loss from urban development; the effects of introductions of exotic species; loss of native fish species to introduced species that are preferred by sports anglers; the potential effects of commercial aquaculture on habitat and native fish species; sediment cleanup decision making and lack of action; and the perception of weak overall environmental management and enforcement records of senior governments in general. Because there is no institutional mechanism to address policy or program concerns of First Nation, Indian and Tribal governments, aboriginal people often deal directly with the management agencies of senior governments on an *ad hoc* basis. In terms of binational issues under the Agreement, Indian governments and organizations have tended to rely on the IJC to voice their concerns to the Parties.

When Administrator Carol M. Browner delineated EPA Indian Policy, she stated that "the core principle of the Policy, a commitment to working with federally recognized tribes on a government-to-government basis to enhance environmental protection, has been reaffirmed by President Clinton and remains the cornerstone of EPA's Indian Policy" (correspondence, the Administrator, U.S. EPA, March 14, 1994). A similar approach to recognize Indian self government, and through devolution to facilitate greater aboriginal involvement in environmental policy, also is being promoted within Environment Canada under its Aboriginal Policy Directorate. (Brant, personal communication November 1998).

In terms of the IJC's role under the *Boundary Waters Treaty of 1909* (International Joint Commission 1990) to prevent and resolve disputes, there is concern that First Nation, Indian and Tribal governments do not participate in the decision making process of the Parties on a governmental basis. While governmental linkages to implement the Agreement include, for example, the Water Quality Board, the Binational Executive Committee and the Canada-Ontario Agreement that foster binational cooperation, the involvement of First Nation, Indian and Tribal governments in Great Lakes decision making at comparable levels has not been evident to date.

Given their organizational capability, economic dependence on the fishery, exposure to toxic substances through consumption of Great Lakes fish and unique ecological knowledge of the lakes, Great Lakes First Nation, Indian and Tribal governments have a role to play with the Parties in their efforts under the Agreement. Their involvement as ***governments*** in Agreement activities is essential to achieving the purposes of the Boundary Waters Treaty.

The SAB recommends the following.

- **The IJC continue to strengthen its consultations with First Nation, Indian and Tribal governments so as to perform its roles of assisting the Parties in the implementation of the Agreement and in preventing and resolving disputes under the Boundary Waters Treaty.**
- **The IJC advise the Parties of the need to involve First Nation, Indian and Tribal governments in the institutional arrangements under the Agreement in order to benefit from their knowledge and expertise, and to enhance binational cooperation in its implementation.**

When Administrator Carol M. Browner delineated EPA Indian Policy, she stated that "the core principle of the Policy, a commitment to working with federally recognized tribes on a government-to-government basis to enhance environmental protection, has been reaffirmed by President Clinton and remains the cornerstone of EPA's Indian Policy" (correspondence, the Administrator, U.S. EPA, March 14, 1994). A similar approach to recognize Indian self government, and through devolution to facilitate greater aboriginal involvement in environmental policy, also is being promoted within Environment Canada under its Aboriginal Policy Directorate. (Brant, personal communication November 1998).

1.8.2 Coupled Great Lakes Observation and Modeling System

Great advances in science and technology have been made during the this century, that can now be applied in the 21st century, to study one of our world's most precious resources — the Great Lakes. The lakes contain 20 percent of the world's fresh water and will undergo ever-increasing pressures from expanding population. Many problems will remain — degraded water quality, contaminants, non-indigenous species, erosion, fishery recruitment, threats to biodiversity, consumptive uses and additional ones will undoubtedly appear. In order to apply a comprehensive ecosystem approach that reflects wise stewardship, new and more efficient methods will be needed.

The 20th Century, characterized by undersampling and reductionist approaches to understanding the Great Lakes, is now completing its course. New capabilities using computers, remote sensing, rapid communications and visualization technology, combined with the accumulated scientific knowledge and expertise of Great Lakes scientists, promise to advance the understanding of how the Great Lakes function and are affected by pollutants.

An early vision of the benefits and challenges of establishing a transboundary monitoring network was described by participants at an IJC workshop convened in October 1984, to explore in a conceptual manner, the need and possibilities for transboundary monitoring network. This work, along with other binational initiatives, such as the air component of Great Lakes International Surveillance Program (GLISP), eventually provided the groundwork and consensus for the establishment of Integrated Atmospheric Deposition Network (IADN) in 1990. IADN is the only current binational monitoring program operating along the transboundary region, comprising a system of master stations on each lake, supplemented by substations established in critical locations. In its recent report *The IJC and the 21st Century*, the IJC noted that many of the basic scientific issues will remain, while the need for management and decision making capacity will increase. Such management needs will require sophisticated techniques and approaches to sustain the integrity of the Great Lakes and implement the Agreement. A comprehensive transboundary monitoring network will provide the following significant benefits:

- greater cost effectiveness over research vessels and manned crews;
- continuous monitoring capability during extreme weather conditions;
- better planning for more detailed field experiments;
- improved management and predictive capability of the state of the lakes;
- direct availability of information on the web for real-time access;
- integration of weather satellite data with lake data on the weather channel;
- the opportunity to take a virtual tour of any or all of the Great Lakes;
- an improved understanding of the complex relationships between sources and pathways of persistent toxic substances;
- increased data sharing and access; and
- protecting public health.

In the early 1980s, Walter Munk, a distinguished physical oceanographer, published a paper *Observing the Ocean in the 1990s* (Munk and Wunsch 1982). In it, he discussed the scientific discoveries that would be possible by joint acoustic tomographic and satellite altimetric observations. The idea was to fuse oceanographic data from different sensors working on different time and spatial scales to achieve a whole greater than the sum of the individual parts. In response, the oceanographic community developed what is called ocean-platform-based measurements that form the basis for the scientific infrastructure that is currently used in ocean research today.

Perhaps the most dramatic example of the progression of experiments and experimental methods comes from the Toga-Tao array (tropical ocean global atmosphere tower array) and Enso (El Nino southern ocean oscillation) events. Early experiments designed to detect the periodic oscillation of warm equatorial water and the coupling with atmospheric models, led to the tremendous advances in our ability to predict the effects of El Nino and La Nina. Remarkable advances in technology have revolutionized and expanded the original ideas of Professor Munk. Electronic devices are getting smaller, cheaper and lighter and require less and less power. These developments, coupled with advances in sensors, batteries and hardware, have led to marked advances in instrumentation.

Ocean platforms and vehicles for instrument deployment have also become smaller, cheaper and more versatile; these platforms and vehicles include submarines, remotely operated vehicles and autonomous underwater vehicles. Geographic positioning systems provide real-time, all weather navigation and positioning capabilities.

The final report to Congress of the National Oceanographic Partnership Program (1999), *Toward a U.S. Plan for an Integrated Sustained Ocean Observing System* (http://core.cast.msstate.edu/chap1.html), concluded that while many observation and monitoring programs exist that serve the current needs of many users, their elements are not integrated, do not constitute a complete system and are not as cost-effective, nor as useful as they could be, even at present levels of funding. The development of a sustained observation program to detect, track and predict physical, chemical and biological changes in oceans is currently underway in the United States.

The scale of research needed to study the world's ocean systems and related international efforts to study global change, necessitates the use of bold and innovative approaches. The application of these techniques, however, to the realm of freshwater research has been modest to date. Nonetheless, technological development is occurring that indicates both the capability and feasibility of integrated and automated monitoring. The development of remote underwater sampling station, by Apprise Technologies Inc., semipermeable membrane devices (artificial fish) that bioaccumulate toxic substances, and the monitoring device developed by the Lambton Industrial Society to monitor spills in the St. Clair River, are a few of the practical examples that are currently in use.

These developments continue to result in substantial improvements in *in-situ* sensing — for various physical, chemical, biological and geological parameters. A number of *in-situ* chemical and biological sensors are capable of measuring the following parameters: pH, O_2, NO_3^-, fluorescence measurements for dissolved organic matter, proteins, and PAHs, CO_2, ATP, Cl^-, and F^-. Several others are under development. Physical sensors, such as those for temperature, current fields, pressure, and conductivity, show continued improvement. Recent advances in molecular biology also hold some promise for biological and chemical sampling. As an example, it is probable that the DNA chip-technology soon will allow researchers to measure picomolar concentrations of chemical contaminants as well as identify types and concentrations of pathogens.

At the same time, there are challenges to overcome. The number of chemicals that presently can be determined *in situ*, particularly those that occur at low concentrations, is still small. Similarly, the number of biological parameters that can be determined remotely is limited. Increased understanding of the Great Lakes depends upon new analytical tools. Thus, rapid improvement in methods are needed, particularly with respect to sensors that can operate *in situ* and for extended time periods.

When combined with advances in communications capabilities, the potential exists to create integrated automated systems, that collect and report information on a real-time basis (see Figure 1). Communication components include satellite links, the Internet and high-speed modems. For example, a new company headed by Gates and McCall will send 288 satellites in low earth orbits (LEO) by 2002. The combination of high-speed low-cost landlines (>155 mbps), with broadband satellite systems will be a

model of the future fusing television, the web, radio and telephony. There will be an increasing capability to view the earth from space at increasingly better resolutions. Resolution is currently being refined from existing weather satellites at approximately 1.1 kilometers (.68 miles) and Landsat-7 at 30 metres (98.43 feet; colour) and 15 metres (49.21 feet; black and white), to new U.S., just released technology, of 0.82 metres (2.69 feet) resolution (Quick Bird). Additional sensors are presently planned, and will provide more detailed information on chlorophyll-*a*, sea-surface temperatures, turbidity, geoids, cloud cover, ice cover and many other parameters.

Concurrent with communication improvements have been the remarkable advances in computers. Moore's Law tells us that computational capabilities will double approximately every 18 months. There is no end in sight for this advance until 15 to 20 years from now, and by then, new technology may replace existing ones.

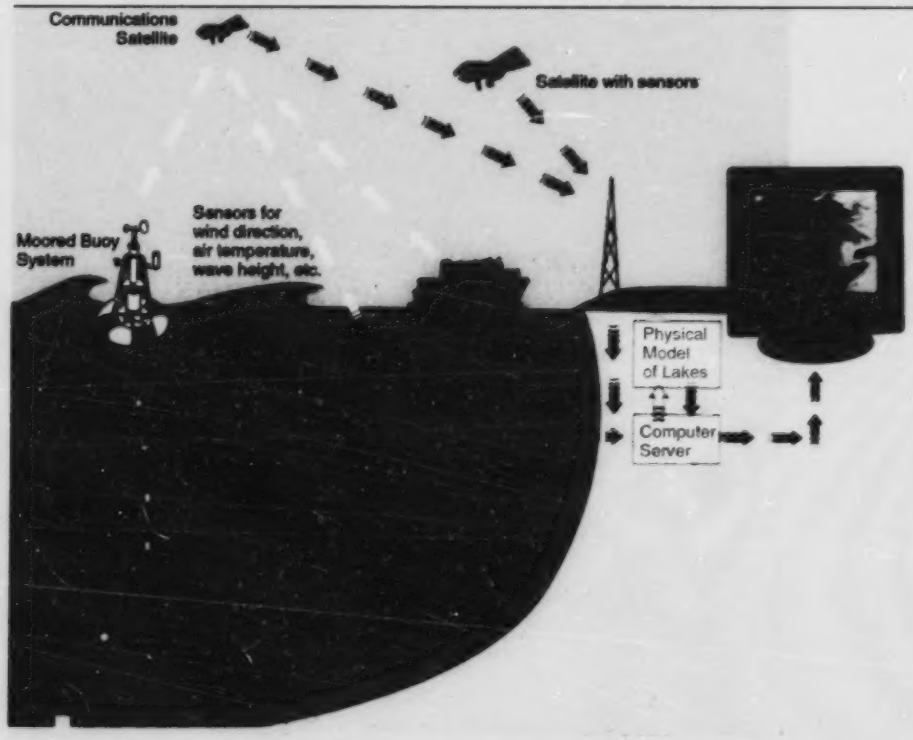
Finally, the field of visualization is now a *bona fide* academic endeavor. This is an area of tremendous importance for several reasons, but two stand out.

1. Data streams are, and will continue to be substantial. One can liken using them as an attempt to drink water out of a fire hydrant. These streams need to be managed and interpreted for understanding and decision making.
2. 3-D and 4-D images are much more effective at conveying information that will enable easier comprehension.

Operational observation systems that combine *in situ* and space derived observations of the Great Lakes in real time, will provide nowcasting and forecasting capabilities on a grand scale. In addition to providing seasonal and longer-term monitoring lake-atmosphere forecasts, the operation of these systems will offer significant capabilities for understanding, managing and protecting the aquatic ecosystem and its resources. Improved technology for measuring biological and physical parameters will enable scientists to make baseline observations that researchers, educators, environmental managers and IJC Commissioners can use at their desks. This capability could include a real-time satellite image (several bands from UV to IR), real-time temperature and current fields, wind speed, and lake-state data. They will be able to use the data with 3-D hydrodynamic models to predict the entire temperature and flow structures of a lake. Three-D physical models will serve as the basis for conveying information in manageable and realistic fashion. The models will be integrated so that they are capable of acquiring real-time physical data from the various hydrological and meteorological sensors. Data from measurements of *in-situ* chemical, biological and geological parameters can then be integrated into the physical model. Thus, it will be possible to produce accurate basic views of water temperature, wave height and current velocities — all as a function of time. It also will be possible to have realistic calculations and observations of mass balances and transport of chemicals, eutrophic state, photosynthesis rates, fish populations, phytoplankton, zooplankton, bacteria and pathogens, as well as calculation of water budgets and levels. A powerful, integrated observational system would enable scientists to achieve a deeper understanding of the Great Lakes basin ecosystem and would also provide a sounder foundation for management decisions.

In order to move forward from the concept to an actual binational system for Great Lakes observation and modeling, the SAB recommends the following.

Figure 1 **A Potential Integrated Automated System to Collect and Report Information on a Real-Time Basis**



- **The IJC promote the development of an information technology system basinwide, as a tool for better management and binational cooperation for the Great Lakes.**

- **The IJC advise the Parties to investigate the feasibility and value of a systematic, cooperative approach to applying information technology to the management and research challenges of the Great Lakes and consider research and technology transfer needs in four specific areas:**
  - **development of a digital Great Lakes computer framework capable of real-time interaction with *in situ* data from physical, chemical, biological and geological sensors;**
  - **realistic three-dimensional coastal water-circulation models capable of nowcasting and forecasting;**
  - **development of distributed computer applications systems that can integrate a variety of multidisciplinary software packages; and**
  - **development of additional chemical, physical, biological and geological *in situ* sensors.**

1.8.3 Survey Results on Emerging Issues

The Workgroup on Emerging Issues has undertaken several surveys to help identify emerging issues, in keeping with the mandate of the workgroup and the Science Advisory Board. During the 1993-95 biennial period, the workgroup solicited advice from the Agreement boards, and surveyed international agencies on emerging issues, (1993-1995 Priorities Report, pages 115-122) and broadened its respondents to include the public and International Association for Great Lakes Research (IAGLR) '97 participants in 1995-97 (1995-97 Priorities Report, pages 37-38). During the 1997-99 biennial cycle the workgroup continued its use of the survey, by posting an electronic format with a hotlink from the IJC homepage, and by specifically inviting State of the Lakes Ecosystem Conference (SOLEC) '98 participants to contribute their input. This was done through the cooperation of SOLEC organizers by placing a survey announcement in conference registration material and by making a hard copy version of the survey questionnaire available at the IJC's Indicators Implementation Task Force poster in the conference display area.

As in previous surveys, this survey was intended to be consultative, and was not designed for the results to be extrapolated to a general population. The issues are considered to reflect the knowledge and expertise of each of the respondents, however, most topics were defined to be in the categories of (a) governance/institutional or (b) social/economic/cultural. These categories were defined in the survey form in order to provide further clarity on each issue. Interestingly, the issues do not indicate that there is need for new scientific knowledge to address them, but rather, a need for a revised/strengthened Agreement, new protocols or further implementation of the Agreement. Although the total number of responses was limited, the submissions were thoughtful and included several respondents from outside of the Great Lakes basin. In terms of salience to the board, three of the issues identified by respondents are related to the 1999-2001 candidate priorities submitted by the board to the Commission: review of Annexes 3 (Control of Phosphorus) and 13 (Pollution from Non-Point Sources), long-term impact of land development and urban sprawl on Great Lakes water quality; and limits of current sewage treatment plant technology.

The summary of all responses is shown in Table 2.

Table 2 **Survey Results on Emerging Issues**

	Issue	Category	Approach	Measure
1	Improved education K-12	Social	Revise Agreement	Program review/evaluation
2	Nonpoint source management to urban growth	Governance	New PLUARG Reference	Policy analysis and program related review/evaluation
3	Zero discharge related to long-range transport	Physical process	Strengthen GLWQA /Annex 15	Policy analysis/ improved monitoring
4	Better understanding of economic theory	Social	More study as in recommendation 19 of Ninth IJC Biennial Report	Policy analysis
5	Identify nonchemical stressors relative to chemical ones	Ecology	Implement existing Agreement	Multidisciplinary analysis involving industry
6	Eliminate persistent organic pollutants globally	Ecology	Implement existing Agreement, international protocols	Monitoring and assessment
7	Better sewage treatment plants and sewer infrastructure	Governance	Implement existing Agreement	Program review/evaluation
8	Virtual elimination of persistent toxic substances	Governance	Implement existing Agreement	Monitoring and assessment
9	Improve institutional arrangements to implement the GLWQA	Governance	Revise Agreement	Program review/evaluation; develop new criteria to assess institutional effectiveness
10	Urban sprawl, land management	Resource	Revise Agreement	Land-use control and monitoring
11	Contamination by pesticides	Physical process	Existing education	Monitor and regulate use
12	Development of gene chips assessments	Physical process	New technology	Improved monitoring and health

It is evident that, while no single emerging issue was seen as outstanding, the responses do indicate a need to sustain effort in particular areas important for Agreement implementation.

As a strategy for eliciting public and scientific response to identify emerging issues, the workgroup views its use of surveys as an important opportunity for individuals to alert the board and the Commission of issues. Its value, therefore, lies in the consultative process. In terms of an approach to future research and analysis, however, it is recognized as only one technique of several that can assist the workgroup and the board. In its seminal work on *Using Foresight to Protect the Environmental Future* (U.S. EPA Science Advisory Board 1995a), the Environmental Futures Committee of the U.S. EPA SAB identified three basic techniques that can be used to gain insight on future conditions:

- scenario development, using backcasting or projections to the future based on likely or desirable events;
- trend analysis based on present day observations and interpretations of experts; and
- scanning, involving the systematic review of published information, contacts with futures watching organizations, or consultation with knowledgeable individuals.

In addition to these techniques, six selection criteria were identified as a basis for determining major issues of importance. They are timing, novelty, scope, severity, visibility and probability (U.S. EPA SAB 1995a, b).

The workgroup intends to apply the concepts and insights developed by the Environmental Futures Committee to provide increased rigor to its own work on emerging issues on behalf of the SAB and the Commission. In its strategic plan approved in June 1998, the IJC stated that in order to sustain and enhance its operational capacity and effectiveness, that it must concentrate its attention, energies and expertise on issues that are of *major significance* [italics added] (IJC strategic plan, Objective 6, approved June 9, 1998). The early identification of such issues enables the Commission to fulfill its valuable alerting role with the governments, with a view to avoiding future water quality problems through coordinated action and response. Rather than prediction, *per se*, therefore, a major strength of future research and analysis is to provide a methodological framework that can be used to assess information, and influence decisions and actions, especially research agendas. (U.S. EPA SAB 1995a, b).

1.8.4 An Emerging Risk from Nitrogen

Recent studies give a basis for concern about environmental effects from the increasing levels of nitrogen in the lower Great Lakes and their tributaries. The problem is evident in the long-term increases in the concentrations of nitrate, and nitrite nitrogen in Erie and Ontario waters, for which data indicate a recent doubling. The trend is driven by moderately high levels of nitrogen in shallow ground water and streams due to the continuing applications of nitrogen fertilizers and the discharge of treated wastewater. Both lakes may now be beyond a doubling from historically very low background levels of nitrogen. Other studies, such as the work of Peierls et al. (1991), indicate up to 100-fold increases in nitrate concentrations in water at the mouth of large rivers draining industrialized or densely populated watersheds, and that phenomenon may need to be examined for the lower Great Lakes.

One well-documented example of the nitrate problem is from a freshwater system, the Illinois River, where mussel die-offs were shown to be probably due to ammonia generated during decomposition of excessively nitrogen-enriched biological productivity (Sparks and Dillon 1993). Recently, risks to amphibian species have been reported for Ontario streams by Rouse et al. (1999) at nitrate concentrations as low as 2.5 mg/L; the U.S. national water quality standard of 10.0 mg/L. Numerous papers have appeared on the apparent role of nitrogen in degrading coastal and estuarine resources and contributing to disease in Chesapeake Bay and other east-coast waters. In 1997, the Ecological Society of America published an Issue Paper on the causes and consequences of change in the global nitrogen cycle. Acidification of soils and waters, and the accelerated loss of biological diversity were among their principal concerns. Also in 1997, there was a full issue of the journal *Ambio* (Hessel 1997) devoted to problems attributable to nitrogen deposition in Europe. Other new research from Wisconsin indicates that exposure to herbicides and commercial nitrogen applications leads to effects on small mammals (Porter et al. 1999). Finally, in December 1998, a report *Emerging Diseases as Indicators of Change - Marine Ecosystems* (Epstein et al. 1998) was released. It focuses on diseases stimulated by nitrogen and other factors, but emphasizes effects on mussels, fish and mammals. A variety of mechanisms are involved, with many leading to risks to human health, and mostly involving nitrogen. Mechanisms include the elevated levels of toxic ammonia forms from decomposition processes; biological toxins from harmful algal blooms (due, in part, to eutrophication); and the suppression of disease defense mechanisms due to lowered carbon nitrogen ratios and related changes in cell metabolism.

Only limited information is available on these concerns for freshwater environments, but the observed trend and environmental effects indicate a need to broaden consideration of risks from nitrogen enrichment at sites within the Great Lakes. Surprises are inevitable in complex resource systems, challenging the state of our science and its role in supporting restoration of "the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." The consequences of elevated nitrogen levels may be one of these surprises.

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1.10 ACTIVITIES AND MEETINGS OF THE SCIENCE ADVISORY BOARD FOR THE 1997-1999 BIENNIAL CYCLE

107	September 3-4, 1997	Cornwall, Ontario Public meeting at the St. Lawrence Institute of Environmental Science and hosted by Mohawk Council of Akwesasne
108	November 19-20, 1997	Sault Ste Marie, Michigan Held at Lake Superior State University St. Marys River Status Assessment
109	February 18-19, 1998	Windsor, Ontario
110	May 27-28, 1998	Windsor, Ontario
111	September 23-24, 1998	Porter/Gary/Hammond, Indiana Grand Calumet Public Meeting
112	November 12-13, 1998	Windsor, Ontario
113	February 25-26, 1998	Windsor, Ontario Special Meeting to Assess Scientific Issues in Relation to Lakewide Management Plans
114	May 13-14, 1999	Windsor, Ontario
115	September 24, 1999	Milwaukee, Wisconsin in association with 1999 Public Forum

1.11 SCIENCE ADVISORY BOARD AND WORKGROUP MEMBERSHIP LISTS FOR THE 1997-1999 BIENNIAL CYCLE

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Mr. Tony Wagner *(Canadian Co-chairman①)*④
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National Water Research Institute
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① Science Advisory Board
② Workgroup on Ecosystem Health
③ Workgroup on Emerging Issues
④ Workgroup on Parties Implementation

NON-BOARD MEMBERSHIP OF WORKGROUPS, LIAISONS AND SECRETARIES

Mr. Bruce Bandurski *(Liaison)*①
International Joint Commission
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Mr. Peter Boyer *(Secretary)*①③
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③ Workgroup on Emerging Issues
④ Workgroup on Parties Implementation

1997-99
Priorities Report
Chapter Two:

THE GREAT LAKES WATER QUALITY BOARD

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2.1 INTRODUCTION

During the 1997-1999 priorities cycle, the Great Lakes Water Quality Board (WQB) was involved in numerous issues. They include Annex 2 of the Great Lakes Water Quality Agreement; reviewing progress of governments in the control and management of persistent toxic substances; review of government programs; contaminated sediment; biodiversity and habitat; and Great Lakes commercial aquaculture.

The WQB uses a four category framework to organize its work, consistent with the Agreement. These categories include:

- physical integrity;
- chemical integrity;
- biological integrity; and
- ecosystem approach.

Highlights of WQB activities and projects during 1997-1999 are presented in Table 1. More detailed information can be found on the WQB's homepage http://www.ijc.org/boards/wqb (.) Brief summaries of key activities and projects are presented below.

Table 1 Highlights of Key WQB Activities and Projects During 1997-1999.

CATEGORY	ACTIVITY/PROJECT
Great Lakes Water Quality Agreement - Ecosystem Approach	• WQB completed and submitted to the Commission a 1998 report titled *Review of Government Resources and Changing Program Thrusts as They Relate to Delivery of Programs Under the GLWQA.* • WQB held a roundtable discussion on the question of, "Does the recent trend of fewer government resources have a bearing on delivery of RAPs and LaMPs?" on May 14, 1999. • WQB helped organize a symposium titled The Decline of Great Lakes Monitoring: Causes and Solutions as part of the 1999 annual meeting of the International Association for Great Lakes Research. • WQB convened its 1998 annual public meeting in Lorain, Ohio on October 8-9 and submitted a final report to the Commission. More than 125 people attended. • WQB members convened a student forum at Oberlin College on October 7, 1998 in conjunction with its annual meeting in Lorain, Ohio. More than 75 students participated. • WQB convened its 1999 annual public meeting in Toronto, Ontario on May 13, 1999. More than 110 people attended. • WQB provided input to IJC on the concept of an International Watershed Board.
Physical Integrity	• WQB co-sponsored a March 4, 1998 conference titled Rehabilitating and Conserving Detroit River Habitats and submitted a final report to the Commission.
Chemical Integrity	• WQB is co-sponsoring with the International Air Quality Advisory Board an October 1999 workshop on Regulating Point Sources of Air Contaminants Based on Violations of Great Lakes Water Quality Standards. • As part of reviewing progress in control and management of persistent toxic substances, WQB members participated in the June 9-11, 1998 Great Waters Workshop in Chicago, Illinois. • WQB's Beyond Compliance Report was published in the November 1998 issue of *Water Environment & Technology.* • WQB's Sediment Priority Action Committee convened a Workshop to Evaluate Data Interpretation Tools Used to Make Sediment Management Decisions at the Great Lakes Institute for Environment Research of University of Windsor on December 1-2, 1998 and prepared a report titled *Deciding When to Intervene.* • Members from WQB's Sediment Priority Action Committee convened a session titled Management of Contaminated Sediment in the Great Lakes Basin and Benefits of Action at the Great Lakes/St. Lawrence Mayors' Conference on July 9, 1998. • Members from WQB's Sediment Priority Action Committee spoke at a Muskegon and White Lake RAP conference titled Cleaning Up Our Lakes, Rivers, and Streams in Muskegon, Michigan on October 2, 1998. (continued next page)

Table 1 Highlights of Key WQB Activities and Projects During 1997-1999, (cont'd).

CATEGORY	ACTIVITY/PROJECT
Chemical Integrity (cont'd)	• WQB's Sediment Priority Action Committee prepared a report titled *Ecological Benefits of Contaminated Sediment Remediation in the Great Lakes Basin.* • WQB's Sediment Priority Action Committee published its contaminated sediment white paper in the *Journal of Great Lakes Research.* • Three case studies of environmental benefits of sediment remediation have been placed on the WQB's homepage. • Work on economic benefits of sediment remediation is underway in partnership with Environment Canada, U.S. Environmental Protection Agency and the Northeast Midwest Institute.
Biological Integrity	• WQB and the Habitat Advisory Board of the Great Lakes Fishery Commission co-sponsored a roundtable discussion on Water Quality Impacts of Great Lakes Aquaculture, January 27-28, 1999 and a report was prepared. • WQB co-sponsored the April 26-28, 1999 conference titled Lake Erie at the Millennium at the University of Windsor.

2.2 REVIEW OF GOVERNMENT RESOURCES AND CHANGING PROGRAM THRUSTS AS THEY RELATE TO DELIVERY OF PROGRAMS UNDER THE GREAT LAKES WATER QUALITY AGREEMENT

In 1997, the Commission requested that the Great Lakes Water Quality Board undertake a review of government resources and changing program thrusts as they relate to delivery of programs under the Agreement. At a minimum, the Commission requested that this review include: monitoring and surveillance activities, Area of Concern commitments and regulatory and enforcement activities.

The WQB initiated a survey in 1997 of key state, provincial and federal agencies with responsibilities for delivery of programs under the Agreement. This survey requested:

- descriptive information on the nature and rationale for recent changes in program thrusts and government resource support as they relate to delivery of programs under the Agreement; and
- economic information on selected indicators of government programs.

Both the descriptive and economic information pertaining to monitoring and surveillance activities, Annex 2 commitments and regulatory and enforcement activities were reviewed and evaluated to gain insight into resource trends within individual jurisdictions and the impact on program effectiveness. The geographical, political and administrative differences among the jurisdictions and between the Parties represented a considerable challenge.

Based on the review of narrative and survey information from 1994-1997 provided by the agencies who responded, the following findings are made.

- Governments are making changes in what they do and how they deliver programs. However, dollars are not a good measure of progress and the WQB does not encourage new investments be necessarily made following historical priorities.
- A one-to-one relationship does not exist between resource expenditures and program delivery.
- Creative partnerships that have been developed and are being developed that share responsibility for program delivery, create efficiencies and build the institutional capacity to achieve ecosystem results.
- Regarding Annex 2 activities, ten of the 15 agencies providing survey data experienced a decrease in funding (>10% decrease), three of the 15 experienced an increase in funding (>10% increase) and two of the 15 showed no change in funding (less than or equal to a 10% increase or decrease) based on a comparison of 1997 data with the average of 1994-1997.
- The IJC should support new and creative initiatives, such as Ontario's Great Lakes Renewal Foundation and the Clean Michigan Initiative, which build the capacity to restore uses through RAPs and LaMPs.
- Regarding monitoring and surveillance activities, nine of the 14 agencies providing survey data experienced a decrease in funding (>10% decrease), one of the 14 experienced an increase in funding (>10% increase) and four of the 14 showed no change in funding (less than or equal to a 10% increase or decrease), based on a comparison of 1997 data with the average of 1994-1997.
- The IJC should support agency proposals to enhance monitoring and surveillance programs targeting key ecosystem indicators.
- Regarding regulatory and enforcement activities, four of the 12 agencies providing survey data experienced an increase in funding (>10% increase), seven of the 12 showed no change in funding (less than or equal to a 10% increase or decrease) and the remaining one experienced a decrease in funding (>10% decrease) based on a comparison of 1997 data with the average from 1994-1997.
- Some agencies reported substantial reductions in resource expenditures in certain programs.
- There is a need to identify how effectively governments are assisting other organizations/institutions in performing the functions previously performed by state/provincial/federal governments (e.g. certain functions under RAPs are now being carried out by county or municipal governments, conservation authorities, watershed councils or nonprofit organizations).
- Continued emphasis must be placed on evaluating program effectiveness based on measuring ecosystem results.

The complete report can be found on the WQB's homepage http://www.ijc.org/boards/wqb/govres/review.html(.)

2.3 PROTECTING WHAT HAS BEEN GAINED IN THE BLACK RIVER

On October 8, 1998 the Black River Remedial Action Plan (RAP) and Great Lakes Water Quality Board co-sponsored a public symposium in Lorain, Ohio. Participants were challenged by the symposium theme of Protecting What's Been Gained in the Black River. More than 125 participants including decision-makers from all levels of governments, industry, environmental groups, faculty and students from surrounding universities and concerned citizens gathered to:

- learn about the progress made in the Black River watershed in recent years;
- share and celebrate successes; and
- provide advice on required future activities to protect and rehabilitate the Black River watershed.

This symposium was an action-oriented public meeting and provided a forum for the exchange of ideas pertaining to watershed management. Research presentations focused on improvements in the river and what remains to be done. Breakout sessions were used to spur interaction between WQB members, Black River RAP Coordinating Committee members, key watershed stakeholders and concerned citizens on specific issues related to the protection and rehabilitation of the Black River watershed.

Key conclusions and recommendations from Symposium Steering Committee include the following:

- Substantial progress is being made in implementing the Black River RAP and restoring uses, such as progress toward elimination of liver tumors in the brown bullhead population and improvements in sediment quality. However, much needs to be done to protect what has been gained and to further rehabilitate degraded areas in the watershed.

- The Black River RAP Committee has taken a leadership role in developing and advancing efforts to protect the Black River and this process needs to be sustained for the future. This community-based process requires the active involvement of informed citizens who are ecologically literate and willing to act as stewards of the watershed.

- Mechanisms should be considered to control urban sediment erosion, manage storm water and address failing residential sewage disposal systems.

- There is a need to more effectively engage the public in understanding and supporting long-term environmental monitoring. Citizens volunteers can have a direct role in this effort, through realistic and practical goals for monitoring programs. To support this, effective training and quality control mechanisms for data collection by volunteers need to be developed.

- The International Joint Commission and the WQB must continue to be champions for community-based RAP processes. The IJC and the WQB are in a unique position to celebrate the progress of RAPs and help sustain community-based RAP groups working to restore and sustain uses in the Areas of Concern.

- The WQB should continue to convene public meetings with RAP groups in Areas of Concern. Such meetings help the public learn more about how local RAP efforts fit into the larger Great Lakes context. These meetings provide important opportunities to meet, share and learn from each other. They also serve as an effective community building project for RAP groups.

The Black River RAP Coordinating Committee is a model for multi-stakeholder cooperation in use of an ecosystem approach to restore uses on a watershed scale.
The complete report can be found on the WQB's homepage http://www.ijc.org/boards/wqb/black/cover.html(.)

2.4 REHABILITATING AND CONSERVING DETROIT RIVER HABITATS

The Detroit River is a 51 km (32 mi) international connecting channel linking Lake St. Clair and Lake Erie. The Detroit River is one of 42 Areas of Concern in the Great Lakes basin ecosystem where a remedial action plan (RAP) is being developed and implemented to restore beneficial uses. The Detroit River RAP identifies "loss of fish and wildlife habitat" as one of the impaired
beneficial uses. Significant loss of Detroit River wetlands and other habitats has occurred as a result of conversion of land to agriculture practices, urban development and industrial growth. For example, 97 percent of the coastal wetlands on the U.S. mainland of the Detroit River have been lost to development and the remaining 3 percent are threatened by development pressures. Further loss of habitat due to contaminated sediment is documented.

On March 4, 1998, the University of Windsor's Great Lakes Institute for Environmental Research, the Citizens Environment Alliance of Southwestern Ontario and other partners, including the IJC's Great Lakes Water Quality Board and Council of Great Lakes Research Managers, convened a binational conference titled Rehabilitating and Conserving Detroit River Habitats. The conference attracted more than 170 participants.

Major conclusions of the conference include the following:

- There is an urgent need to protect the few remaining natural areas along the Detroit River.
- Management agencies must take the lead in using available guidance tools to set priorities for habitat rehabilitation and conservation, such as Environment Canada's A Draft Framework for Guiding Habitat Rehabilitation in the Great Lakes Areas of Concern, and move forward with habitat rehabilitation and conservation projects.
- Individuals and organizations with habitat expertise need to be prominently involved early in the planning processes for waterfront development, shoreline modification and similar projects.
- Habitat rehabilitation and conservation projects should be recognized as important experiments from which we can learn -- program managers must therefore explicitly link research/monitoring with planning and management of habitats.
- Greater emphasis must be placed on quantifying economic, social and ecological benefits of habitat rehabilitation and conservation projects.

Habitat rehabilitation and conservation projects should be recognized as important experiments from which we can learn – program managers must therefore explicitly link research/ monitoring with planning and management of habitats.

The conference report reflects the high level of commitment that agencies, universities and the public have made to reverse the trends of erosion of quality and quantity of aquatic habitat in the Great Lakes basin ecosystem. This work is especially important because participants are committed to improving the Detroit River corridor, where it would be easy to write-off the area and look elsewhere for the investment of limited resources. The support by WQB and Council of Great Lakes Research Managers for this conference sends a clear message that aquatic habitat is important to the Great Lakes community.

The WQB recommends the following.

- **The IJC continue to track progress in habitat management and repair, and that, without adequate attention by the Parties, that part of the Purpose of the Agreement that speaks to *biological integrity* may not be achieved.**
- **The Commission to recommends to the Parties, appropriate jurisdictions and stakeholders in the Detroit River Remedial Action Plan (RAP) that they take into account the recommendations from the conference into their efforts to further develop and implement remedial and preventive actions to restore impaired uses in the Detroit River.**

The complete report can be found on the WQB's homepage http://www.mnsi.net/~cea/drhc/cover.html(.)

2.5 REGULATING POINT SOURCES OF AIR CONTAMINANTS BASED ON VIOLATIONS OF WATER QUALITY STANDARDS

As part of a continuing priority on significant sources, pathways and reduction/elimination strategies for persistent toxic substances, the WQB and the International Air Quality Advisory Board are collaborating to explore the ability to take regulatory action against a point source of air pollution based on violations of water quality standards. Technical and legal scenarios appropriate to Canada and the U.S. are being prepared, as are legal briefs designed to explore the applicability of legal tools to address the issue in both countries. The scenarios and legal arguments -- pro and con -- will be presented at a moot court event, to be held October 26-27, 1999 at the University of Windsor.

2.6 CONTAMINATED SEDIMENT

2.6.1 DECIDING WHEN TO INTERVENE - Data Interpretation Tools For Making Sediment Management Decisions Beyond Source Control

There is consensus among diverse sectors in the Great Lakes basin, such as government, industry, non-governmental organizations and Remedial Action Plan groups, that contaminated sediment is an important element leading to many beneficial uses impairments around the Great Lakes. All 42 Great Lakes Areas of Concern have sediment classified as contaminated based on sediment quality guidelines for chemicals. This universal obstacle to environmental recovery in Areas of Concern is a challenge to restoring 11 of the 14 beneficial uses identified in the Agreement.

Sediment management decisions for Remedial Action Plans need to be made bearing in mind the relationship between contaminated sediment and restoration of beneficial uses. This goes far beyond setting a numerical chemical cleanup criteria, as these are not based on the need to fully restore beneficial uses. What is needed is a pragmatic decision-making framework that leads to the selection of ecosystem and cost-effective options for management of contaminated sediment.

The Great Lakes Water Quality Board has called for a stepwise and incremental approach to management of contaminated sediment and restoration of beneficial uses. Sediment remediation, removal by dredging of a mass of contaminants, and reduction of risk are important indicators of incremental progress. The ultimate success of sediment management activities will be judged upon restoration of beneficial uses such as elimination of fish consumption advisories, restoration of fish and wildlife populations and restoration of benthos.

The complete report can be found on the WQB's homepage http://www.ijc.org/boards/wqb/sedrem.html (.)

Bioassessment frameworks have evolved substantially, and in many cases, large data sets have the required elements for developing a sediment management strategy. Equally important to the collection of data, however, is that sufficient attention be placed on thorough and comprehensive interpretation of the data. By employing scientifically sound methods of data interpretation, the information from an intensive sediment assessment can be integrated to make a decision whether to intervene (i.e. remediate contaminated sediment) or pursue source control and natural recovery as the preferred remedial option.

On December 1-2, 1998, the WQB's Sediment Priority Action Committee (SedPAC) convened a workshop at the University of Windsor to evaluate data interpretation tools used to make sediment management decisions beyond source control. A workshop report has been prepared. The primary intent of the report is to share advances in data interpretation regarding sediment management decision-making with RAP practitioners. Presently, a great deal of data have been collected on the physical, chemical and biological elements that modify contaminant bioavailability and ecological effects. This literature can help guide RAP practitioners through a transparent, use restoration decision-making process.

In addition to this review of data interpretation tools, the SedPAC recognizes that the IJC can offer more assistance in the efforts to overcome obstacles to sediment management.

Specifically, SedPAC recommends the following.

- **The Parties and jurisdictions develop and reach agreement on methods or programs to predict and measure successful ecological recovery in Areas of Concern such as ecological benefit forecasting, monitoring and surveillance programs to measure use restoration.**

- **The Parties and jurisdictions establish procedures for consistent data collection and interpretation across Areas of Concern, recognizing the importance of site specificity in applying methodologies and tools.**

The Commissioners also have an important role to fulfill in overcoming obstacles to sediment management for beneficial use restoration.

SedPAC recommends the following.

- **Commissioners develop and implement an IJC public outreach strategy to help make contaminated sediment management a priority throughout the basin.**

There are currently few, if any, simple or proven methods to predict recovery of use impairments based on sediment cleanup. More research is needed to quantify the relationships between contaminated sediment and known use impairments. The concept of ecological benefit forecasting (i.e. predicting ecological benefits and restoration of beneficial uses) is an important management need, which if accomplished, would be a substantial step forward.

Finally, deciding when to intervene is embedded with multiple elements. Data interpretation tools and techniques are a central element in developing the sediment management strategy. This workshop report is one in a series that will explore a number of aspects affecting sediment management. Other aspects involve what is and is not known about linking sediment cleanup to ecological recovery and restoration of beneficial uses, as well as economic benefits that may accrue from effective management of contaminated sediment.

The complete report can be found on the WQB's homepage http://www.ijc.org/boards/wqb/sedwkshp(.)

2.6.2 ECOLOGICAL BENEFITS OF SEDIMENT REMEDIATION IN THE GREAT LAKES BASIN

Over the past 20 years, considerable progress has been made in the control and management of point and nonpoint sources of chemical contaminants. Reduced loadings of contaminants have, in general, resulted in a 50-70 percent reduction of contaminant levels in fish between the early 1970s and the mid 1980s. However, since the mid 1980s, ambient levels of contaminants appear to have generally either leveled off or their rate of decrease has slowed substantially. Fish consumption advisories remain in effect in all of the Great Lakes. It is believed that the major reason why contaminant levels in fish have generally leveled off and health advisories on human consumption of fish remain in effect is that there are continued inputs of contaminants from the atmosphere, groundwater discharge, surface runoff and contaminated sediment. The lakes have also become now a source of contaminants to the atmosphere, which in turn, deposits contaminants back into the lakes.

The importance of the contaminated sediment issue continues to escalate in both the United States and Canada. For example, U.S. Environmental Protection Agency's (EPA) Region 5 has identified cleaning up contaminated sediment as one of its top five priorities in its Agenda for Action for fiscal years 1998 and 1999. The Agenda for Action states that:

> "Polluted sediments are the largest major source of contaminants to the Great Lakes food chain, and over 97% (8,325 km)of the shoreline is considered impaired. The Region V inventory contains 346 contaminated sediment sites. Fish consumption advisories remain in place throughout the Great Lakes and many inland lakes. Contaminated sediments also cause restriction and delays in the dredging of navigable waterways, which in turn can negatively affect local and regional economies. Contaminated sediments must be cleaned up before they move downstream or into open waters, which makes them inaccessible and cleanup impossible."

Contaminated sediment has been identified as a source of ecological impacts throughout the Great Lakes basin. While contaminated sediment is not designated as a specific impairment in Annex 2 of the Great Lakes Water Quality Agreement, in-place pollutants potentially pose a challenge to restoring 11 of the 14 beneficial use impairments: restrictions on fish and wildlife consumption; degradation of fish and wildlife populations; fish tumors or other deformities; bird or animal deformities or reproductive problems; degradation of benthos; loss of fish and wildlife habitat; eutrophication or undesirable algae; degradation of phytoplankton or zooplankton populations; degradation of aesthetics; added costs to agriculture or industry; and restrictions on dredging activities.

The 14 beneficial uses identified in the Agreement can be grouped into four aspects of ecosystem health or state: human health, societal value, economic value and ecological performance. The first eight of the 11 beneficial use impairments identified above deal with ecological performance. Therefore, restoration of their use and the realization of ecological benefit requires an understanding of the relationship between contaminated sediment and a specific use impairment. It is also imperative, prior to embarking upon sediment remediation, to have developed some quantifiable expectation of result ecological benefit and a program to monitor the predicted recovery.

In most Areas of Concern, documentation of the sediment problem has not been quantitatively coupled to the ecological beneficial use impairments. Therefore, stipulating how much needs to be cleaned up, why, and what improvements can be expected to the beneficial use impairment(s) over what time frame has not been possible. A clear understanding of these relationships and some level of quantification is critical for the development of a complete sediment management strategy. This understanding should provide adequate justification for an active cleanup program, and also represents a principle consideration in the adoption of non-intervention alternative strategies. In developing this understanding, it is important not only to know the existing degree of ecological impairment associated with sediment contaminants, but also the circumstances under which those relationships and impacts might change, such as contaminants becoming more available or more detrimental.

Over the past 13 years, over $570 million has been spent on 37 sediment remediation projects in 19 Areas of Concern. Of these projects, only two currently have adequate data and information on ecological effectiveness (i.e. post-project monitoring of beneficial use restoration). In some cases there is planned monitoring of ecological effectiveness, but the data will not be available for a number of years. In the cases where sediment remediation was undertaken as a result of regulatory action, the projects removed a mass of contaminants to reduce environmental risk. These projects were very effective in meeting the regulatory requirements, and are consistent with the step-wise and incremental approach to management of contaminated sediment called for by the WQB. However, it is recognized that in many cases, much more effort should be

placed on forecasting and assessing ecological recovery of an Area of Concern, as well as beneficial use restoration consistent with Annex 2 of the Agreement.

Therefore, it is recommended that:

- **much greater emphasis be placed on post-project monitoring of the effectiveness of sediment remediation. The assessment of effectiveness relative to restoration of uses with appropriate quality assurance and quality control.**

One way of achieving post-project monitoring of sediment remediation effectiveness would be for the state/provincial/federal agency staff responsible to have specific commitments and resources required to incorporate into settlements and cooperative agreements. Good examples of this include the Welland River project (Ontario), the settlement under the National Resources Damage Assessment for Saginaw River and Bay (Michigan) and the Thunder Bay cleanup project (Ontario).

It is recognized that ecological benefits of partial sediment remediation may not be measured because of the magnitude of the contaminated sediment problem in the area and in remaining downstream areas of contamination, which would mask or delay ecological recovery, such as in the Grand Calumet River/Indiana Harbor Ship Canal. Areas of Concern where the probability of measuring ecological benefits of sediment remediation is high include: Manistique River, Collingwood Harbour, River Raisin, Newburgh Lake Impoundment on the Rouge River and the Maumee River.

Sediment Priority Action Committee recommends:

- **a high priority be placed on monitoring ecological benefits and beneficial use restoration at sites where sediment remediation has taken place.**

Although a basic understanding of aquatic ecosystem function and chemical fate is generally available, aquatic ecosystems appear to be sufficiently unique and our understanding sufficiently lacking, that an adaptive management approach (i.e. assess, set priorities and take aciton in an iterative fashion) is the prudent course to follow. This approach requires a much tighter coupling of research, monitoring and management, in every case, to develop quantifiable, realistic goals and measures of success or failure to achieve them.

Clearly, there are knowledge gaps in our understanding of the relationship between contaminated sediment and the 11 use impairments from the Agreement that are potentially impacted by contaminated sediment.

Therefore, the Sediment Priority Action Committee recommends that:

- **additional research is essential to quantify the relationships between contaminated sediment and known use impairments, forecast ecological benefits, and monitor ecological recovery and beneficial use restoration in a scientifically-defensible and cost-effective fashion.**

The complete report can be found on the WQB's homepage http://www.ijc.org/boards/wqb/ecolsed(.)

2.6.3 ECONOMIC BENEFITS OF SEDIMENT REMEDIATION

There are few quantitative studies that assessing the economic benefits of remediating contaminated sediment. There are at least two reasons for this. First, attention to the economic aspect of sediment contamination has been relatively recent. Historically, economic analyses were undertaken in conjunction with navigational dredging. These analyses focussed largely on the economics of dredging and disposal. By the mid-1980s, the focus in the Great Lakes had begun to shift to consider the broader ecological impacts, in part due to the 1987 revisions to the Great Lakes Water Quality Agreement. The second reason is that documentation of sediment contamination has not been quantitatively coupled to the ecological beneficial use impairments. Of the 37 sediment remediation projects undertaken in the last 13 years in Great Lakes Areas of Concern, only two have adequate information and data on ecological effectiveness. The lack of quantitative biophysical data makes it difficult to instil confidence in the estimation of economic benefits, which in turn deters economic analysis.

Nevertheless, anecdotal information indicates that the economic benefits from sediment cleanup could be substantial. For example, vessels entering Waukegan Harbor (Illinois) can only be filled to 40 percent capacity because of draft restrictions related to sediment contamination. This *light-loading* of vessels results in millions of dollars of lost revenue annually could be avoided when a suitable remedial strategy for contaminated sediment is finally implemented yielding considerable economic benefits to Waukegan Harbor industries.

Preliminary analysis in Thunder Bay, Ontario indicates the cleanup of sediment at the Northern Wood Preservers site could be linked with potential economic benefits from waterfront development. In this case, the city of Thunder Bay has approximately $50 million of proposed waterfront redevelopment plans, some of which are linked to cleanup of this site. It is suggested that remediation of contaminated sediment at the Northern Wood Preservers site will be a catalyst for helping to realize the economic waterfront development opportunities to their fullest extent. Without cleanup, some of these opportunities may not be realized.

Towards developing more information on the potential economic benefits of contaminated sediment remediation, the Great Lakes Water Quality Board's Sediment Priority Action Committee collaborated with the Northeast Midwest Institute in preparing its Great Lakes Valuation Guidebook during the 1997-1999 biennial cycle. SedPAC is now working with experts from the Parties, jurisdictions and the Northeast Midwest Institute to encourage undertaking case studies of economic valuation.

While some benefits assessment work is currently underway in the St. Clair River Area of Concern, more case studies using a

range of economic valuation methods are needed. These case studies will help identify the nature and extent of potential benefit types and identify those valuation methodologies best suited for the local characteristics of a remediation site. Potential benefit categories include:

- use benefits (e.g. fishing, swimming and boating);
- avoided costs (e.g. navigational dredging and human health);
- economic development opportunities (e.g. waterfront development investments previously deferred and attracted businesses);
- property value (e.g. land value impacts); and
- non-use/sustainability benefits (e.g. bequest and existence values often associated with biodiversity and habitat).

Identifying the potential benefits of remediating contaminated aquatic sediment can help raise the profile of the problem and expedite and strengthen the decision as to whether cleanup is warranted in a given site. Raising the profile also can help identify possible funding opportunities, stimulate corporate involvement and generate local support when a decision to intervene has been made.

Identifying the potential benefits of remediating contaminated aquatic sediment can help raise the profile of the problem and expedite and strengthen the decision as to whether cleanup is warranted in a given site. Raising the profile also can help identify possible funding opportunities, stimulate corporate involvement and generate local support when a decision to intervene has been made.

2.7 ADDRESSING CONCERNS FOR WATER QUALITY IMPACTS FROM LARGE-SCALE GREAT LAKES AQUACULTURE

Aquaculture is an emerging issue in the Great Lakes basin caused by an increased demand for freshwater fish and by concern for a rapid expansion of a relatively new industry. Globally, the current demand for seafood has increased to the point where the United Nations estimates that nearly one-quarter of the protein in human diets is derived from seafood, of which 21 percent of the world consumption of seafood comes from aquaculture. With the rapid expansion of aquaculture there has been an increased concern for the impacts the industry might have on water quality and biota, as well as economic and social benefits.

As part of the Great Lakes Fishery Commission mandate to assess habitat alterations and recommend mitigative strategies to address concerns for aquaculture in the Great Lakes basin, a roundtable discussion of water quality impacts of Great Lakes aquaculture was held on January 27-28, 1999 in collaboration with the Great Lakes Water Quality Board. Water quality impacts (i.e. elevated phosphorus levels, increased primary productivity and reduced water transparency). due to hatchery operations have been documented in Michigan's Platte Lake. In addition, water quality impacts due to caged aquaculture have been documented in Minnesota lakes (i.e. approximately an order of magnitude increase in water column phosphorus, nitrogen and chlorophyll levels and increased attached algal growth) and in Ontario on the North Channel and Georgian Bay of Lake Huron (i.e. elevated phosphorus levels, reduced water transparency, algal blooms and dissolved oxygen depletion over 250 ha). Industry representatives provided information that other operations in Georgian Bay have been well managed and have not resulted in any significant water quality problems. Roundtable participants were of the opinion that water quality problems can be substantially prevented with better assessment, siting, prediction of carrying capacity and management of food, fish and waste.

Caged aquaculture operations in the Great Lakes are currently limited by available technology. Neither cage nor land-based aquaculture is expected to grow substantially. The aquaculture industry is interested in achieving economically-viable and environmentally-sustainable operations. Both the aquaculture industry and governments want to limit water quality and habitat impacts.

Caged aquaculture operations in the Great Lakes are currently limited by available technology. Neither cage nor land-based aquaculture is expected to grow substantially. The aquaculture industry is interested in achieving economically-viable and environmentally-sustainable operations.

One promising analytical tool, sponsored by the Great Lakes Fishery Commission, is being developed to prevent water quality impacts from aquaculture and prevent introductions of exotic species. This decision support system titled Environmental Assessment Tool for Private Aquaculture in the Great Lakes Basin is being developed by the University of Minnesota. This user-friendly, computer-based system is designed to help direct impact assessments and guide risk management decisions regarding private aquaculture operations.

Based on a review of the information and discussions from the roundtable, and the extended abstracts presented in this report, the roundtable steering committee has made the following recommendations.

- **Jurisdictions/government agencies perform better site assessments as part of the application for all new caged aquaculture operations, including site specific prediction of carrying capacity (e.g. the University of Minnesota Environmental Assessment Tool could be field tested on new permit/ license applications)**
- **Limit caged aquaculture operations based on a feed quota**
- **Routine monitoring program be required as part of each caged aquaculture license or permit (e.g., benthic community structure, chemistry, periphyton, etc.)**
- **Best management practices be develop and implement BMP for all caged aquaculture operations.**

It is recommended that the Great Lakes Fishery Commission and the International Joint Commission:

- **continue to track the issue of water quality impacts from Great Lakes aquaculture; and**
- **ensure that related aquaculture issues of comprehensive disease management, introduction of exotic species, use of therapeutics and antifoulants be addressed in the future.**

It is recommended that the following research needs be addressed:

- **development and application of simple, rapid, bioassessment tools and practical early warning indicators for signs of changing benthos, phytoplankton and zooplankton;**

- development and application of models to estimate carrying capacity and predict site suitability for aquaculture operations;
- frequency, extent and feasibility of fallowing or resting a site required to minimize impacts;
- nutrient/energy efficiencies of fish feed;
- efficacy of alternative nutrient abatement technologies;
- impacts of caged aquaculture operations on structure and function of the fishery; and
- relative impact of existing land-based aquaculture operations.

It is recommended that the aquaculture industry:

- cage-culture aquaculture applicants assess the carrying capacity of the proposed site and allocate waste loadings within that capacity;
- adequate pre- and post-operational monitoring be conducted;
- efforts be made to involve all stakeholders early-on (e.g. cottage owners) in planning to gain acceptance and avoid problems;
- fish farmers consider using highly digestible, nutrient dense diets that are less polluting and could prove cost-effective for fish production; and
- fish farmers consider developing an environmental management system under ISO 14000 that incorporates use of best available technologies and requires adequate monitoring for continuous improvement in operations.

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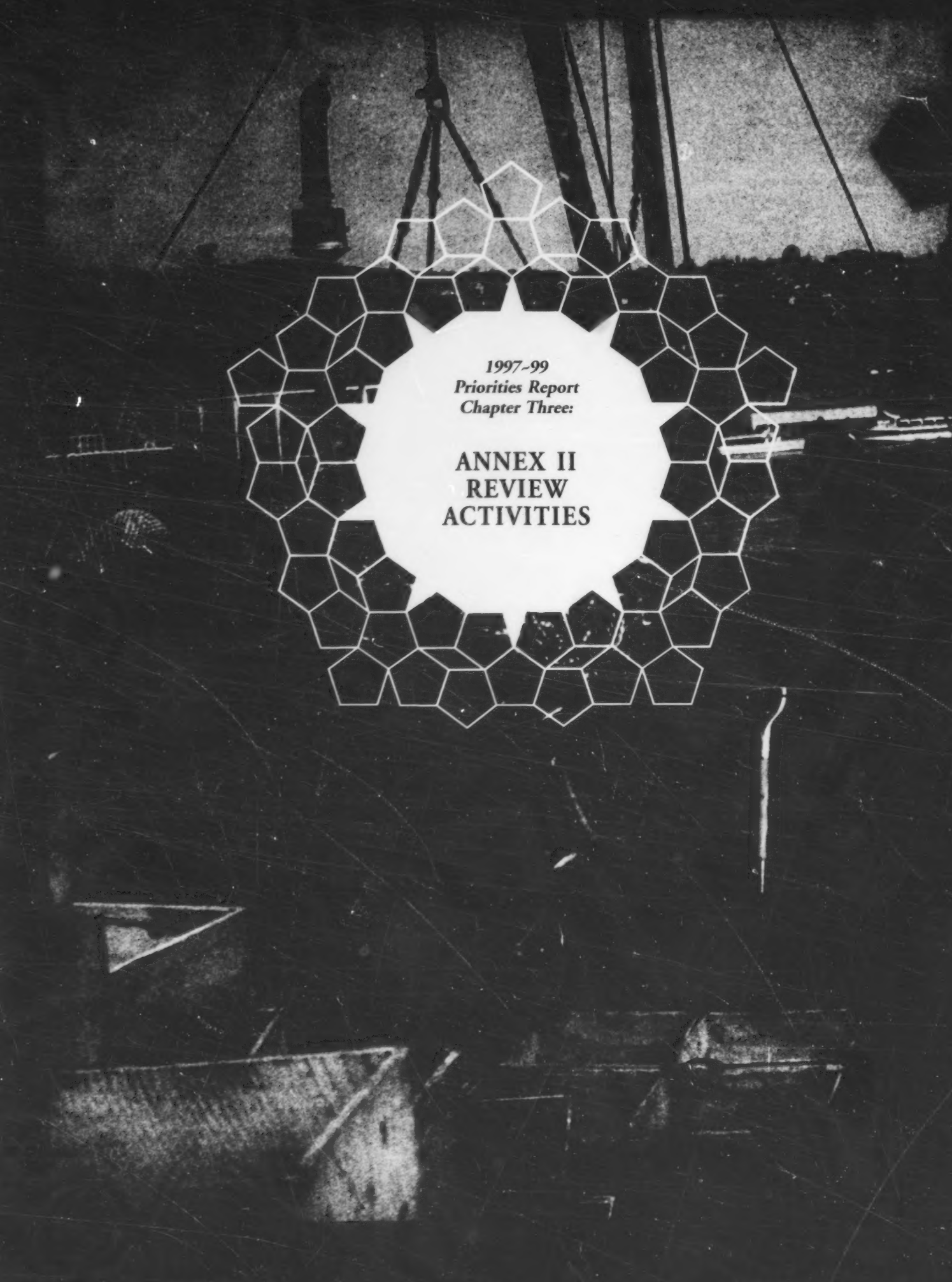

1997-99
Priorities Report
Chapter Three:

ANNEX II REVIEW ACTIVITIES

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3.1 INTRODUCTION

Over the past few years, the International Joint Commission (IJC) has implemented its new approach, adopted in April 1996, toward Annex 2, Remedial Action Plan (RAP) and Lakewide Management Plan (LaMP) activities. A principal component of this approach involves proactively conducting Status Assessments to evaluate progress under Annex 2 of the Great Lakes Water Quality Agreement (GLWQA). This evaluation tool allows the IJC to more effectively fulfill its role of reviewing progress and assisting in implementing the GLWQA without waiting for RAPs or LaMPs to be submitted by the Parties for review and comment. Two Status Assessments-the Detroit River Area of Concern (AOC) and the St. Marys River AOC-were completed within the 1997-99 priority cycle. Findings from these Status Assessments and other initiatives are presented below.

The IJC recommends "human health information being developed for LaMPs be incorporated as appropriate into the RAP development process." It is noted that this information should provide considerable justification for many needed remedial actions.

3.2 HUMAN HEALTH CONSIDERATIONS IN LAKEWIDE MANAGEMENT PLANS AND REMEDIAL ACTION PLANS

One of the principal requirements of any Stage 1 LaMP for Critical Pollutants is the definition of the threat to human health or aquatic life. Toward this and other needs, major research efforts funded largely by the Agency for Toxic Substances and Disease Registry and Health Canada have been conducted in the Great Lakes basin. Table 1 outlines findings from ten such studies that have been conducted in the Basin. Accordingly, considerable data exist to define the threat to human health posed by the exposure to Critical Pollutants through the consumption of environmentally contaminated Great Lakes fish or wildlife. For additional information on defining the threat to human health see the Indicators Section on fish consumption advisories on page 85 and the Science Advisory Board (SAB) section on LaMPs starting on page 18.

As a basis for addressing this issue, LaMPs need to identify and assess the extent of human populations in their basins that are particularly susceptible to health risks from toxic substances and initiate measures to alleviate those risks that fall within the purview of LaMPs. In its review of the Stage 1 Lake Superior LaMP [http://www.ijc.org/boards/annex2/lslamp.html], the IJC (1996) notes "few data are presented linking exposure to specific Critical Pollutants to threats to human health . . ." The IJC, in its review comments on this Stage 1 LaMP further states "The document submitted to the Commission relied heavily on information available from previously published RAPs, which by definition, do not focus on open lake waters . . . most RAPs, to date, have not focused explicitly on human health concerns and as a result neither does the Stage 1 Lake Superior LaMP." For reasons which remain unclear, a primary LaMP requirement [definition of the threat to human health . . .] outlined in Annex 2 of the GLWQA remains unmet for the Lake Superior LaMP. In its Ninth Biennial Report on Great Lakes Water Quality (IJC 1998a), the IJC notes "Although one LaMP requirement is to define the threat to human health posed by Critical Pollutants, in the more than six years of LaMP development this generally has not yet occurred."

The lack of data in regard to the implications of persistent toxic substances on human health has also been a concern in the RAP process. In the report (IJC 1998b) Beacons of Light: Successful

Strategies Toward Restoration in AOCs [http://www.ijc.org/boards/annex2/beacon/beacon.html], the IJC comments that it is important to place cleanup costs in perspective by better defining the health benefits that can be derived from the remediation of contaminated sediment. The IJC recommends "human health information being developed for LaMPs be incorporated as appropriate into the RAP development process." It is noted that this information should provide considerable justification for many needed remedial actions. Of particular concern, to the IJC, are susceptible

Table 1 Findings in Human Populations - Exposure Studies

Population	Findings	Reference
Lake Michigan fisheaters cohort	PCB levels in breast milk and maternal serum correlate with consumption of contaminated fish.	Humphrey 1983
Native Americans (Mohawk) in New York State	Mean serum PCB levels in men was 5.4 parts ppb (max. 31.7 ppb), versus 5-7.7 ppb in the general population (Jensen 1989). Serum PCB levels were positively related to the number of fish meals consumed per year and increasing age.	Fitzgerald *et al.* 1996
Elderly cohort of Lake Michigan sport anglers	PCBs, DDE, and mercury levels were significantly higher in high fisheaters. High fisheaters presented disproportionately higher body burden levels of PCBs and DDE than low fisheaters in each age group, i.e., 50-59, 60-69.	Schantz *et al.* 1996
Pregnant women who consumed Lake Ontario fish	Women in the high-fish-consumption group ate an average of 2.3 salmon or trout meals per month for an average of 16 years.	Lonky *et al.* 1996
Pregnant African-American women who consumed Lake Michigan fish	Women were exposed to PTSs via fish consumption during most of their reproductive years. Seventy-five percent were less than 26 years of age and consumed lake fish for more than 15 years.	Waller *et al.* 1996
Reproductive age (18-34) Lake Michigan sport anglers	Approximately 50% ate 1 to 12 sport-caught meals in the past year, and 20% consumed 13 to 24 meals. Fish consumption was greater in males than females, with some males consuming 49 or more fish meals per year.	Courval *et al.* 1996
Charter boat captains, their spouses, and Great Lakes anglers	Serum levels of dioxin, furans, and coplanar PCBs vary by gender, and fish species predict coplanar PCBs and furan body burden levels but not dioxin.	Falk *et al.* 1997
Asian origin sport anglers on the St. Lawrence River	Bangledeshi fisheaters consumed an average 46.8 sport fish meals and Vietnamese fisheaters ate 40.7 meals, considerably less than the average 57 sport fish meals eaten annually by native Quebecers.	Shatenstein *et al.* 1997
3,751 individuals from five Canadian Great Lakes Areas of Concern (AOC)	Individuals are consuming species for which local guidelines do not exist, preparing fish in different ways, and eating fish more frequently than in current recommended guidelines.	Cole *et al.* 1997
Canadian fishermen from the St. Lawrence River basin	Mercury intake exceeded acceptable daily doses for the most contaminated fish species. PCBs estimated intake was 10 to 100 times lower than the daily acceptable dose.	Gauvin *et al.* 1997

Adapted from Johnson *et al.* 1998.

human populations consuming sport-caught fish within various AOCs. For example, the Status Assessment (IJC 1999) of restoration efforts in the St. Marys River Area of Concern [http://www.ijc.org/comm/stmarys/status.html] states "While undertaking this status assessment, the IJC found no evidence of specific outreach [communication] programs directed at the most impacted subset of the AOC's population, the Native American/First Nation population."

In its review of the Nipigon Bay Stage 2 RAP (IJC 1998c) [http://www.ijc.org/boards/annex2/nipigon/stage2rev.html], the IJC states "The Stage 2 RAP does not evaluate the benefits that would be derived by First Nations from the restoration and protection of the beneficial uses that historically existed, including a range of economic and health implications." In the case of the Nipigon Bay RAP, no discussion of consequences to the First Nations' fishers who were historically dependent on the now impaired fishery [impaired through loss of habitat and degraded fish populations] is provided. Thus, it will be difficult if not impossible to discern any benefits that may accrue to First Nations through restoration of the fish population. If benefits are not readily visible, it is difficult to justify aggressive and costly remedial activities. The lack of suitable information precludes a reasoned choice from among the alternative actions that are available for possible implementation. This difficulty does not, however, mean that economically significant impacts to the human and natural environment have not occurred.

The IJC and its SAB have applied considerable resources and efforts toward enhancing LaMP and RAP personnel's access to pertinent information on the human health effects of consuming environmentally contaminated Great Lakes fish [see SAB discussion on page 18]. These efforts have included a September 1997 workshop conducted in Cleveland, Ohio and a February 1999 SAB meeting held in Windsor, Ontario. To date, LaMPs have not adequately identified susceptible human populations in their respective lake basins. As a result, the threat to human health posed by Critical Pollutants has not been well defined in any LaMP. Consequently, despite numerous relevant studies, limited human health information exists in LaMPs that can incorporated, as previously recommended by the IJC, into RAPs. If available, this information would serve to better justify remedial activities in AOC restoration efforts and to better identify and inform susceptible populations.

3.3 SUITABLE COMPARISON OF REMEDIAL OPTIONS IN AOCS

The failure to identify susceptible human populations has made it difficult for RAP participants to discern human health risks that exist due to the consumption of environmentally contaminated fish. Hence, it is difficult to perceive benefits that may be derived from reducing these risks through remediation of contaminated sediment [see Water Quality Board discussion on page ___], a major contributor to the environmental contamination of Great Lakes' fish. This information should be considered important regarding the selection of appropriate remedial strategies, including the recognition that active mitigation measures may be required. Otherwise, it may be easier to accept a no or low-cost [caretaker] approach to remediation. Flawed decision-making could result from the failure to examine a full range of possible alternative actions or the failure to define environmental benefits including the enhancement of human health conditions foregone through selection of a no- remediation alternative.

In an era of Parties' funding and program cutbacks, there exists an institutional preference for the no or low-cost [caretaker] alternative. Alternative plans should be formulated in a systematic manner in order to assure public consultation and selection of the most desired action. Usually, a number of alternatives can be identified early in the planning process and become more refined through additional development and subsequent iterations (U.S. Water Resources Council 1983). An interdisciplinary approach including, as needed, human health professionals is necessary to ensure that possible alternative actions can adequately address previously defined environmental problems. To date, human health benefits and human health benefits foregone in the case of no-remediation alternatives have not been adequately addressed. This is particularly true in the cases of AOCs with existing contaminated sediment problems but with no obvious funding mechanisms.

To date, human health benefits and human health benefits foregone in the case of no-remediation alternatives have not been adequately addressed. This is particularly true in the cases of AOCs with existing contaminated sediment problems but with no obvious funding mechanisms.

3.4 PUBLIC CONSULTATION AND PARTICIPATION

Public consultation is an ongoing requirement in regard to actions taken pursuant to Annex 2 of the GLWQA. This requirement is not reduced once the Parties begin the selection and implementation of appropriate remedial actions. On the contrary, engaging the knowledgeable public in this ongoing process can enhance the timely implementation of locally-acceptable remediation alternatives. Public acceptance of planned remedial measures including the no-cost [caretaker] alternative is critical to the viability of any selected action. In particular, consultation with the more susceptible subset of the population is necessary before any proposed action can be judged acceptable. In some cases, such as the Nipigon Bay AOC, this needed consultation does not appear to be occurring.

The Status Assessment (IJC 1997a) of the Detroit River Area of Concern also notes [http://www.ijc.org/boards/annex2/detroit.html] this problem of inadequate citizen involvement and consultation, to the detriment of progress under the RAP and the required public commitment to it. The status assessment states "There is too little public awareness or acceptance of the need to restore uses in the Detroit River." The St. Marys River Status Assessment likewise examines public consultation concerns and determines "Numerous lead agency staffing changes and an apparent lack of oversight have contributed to problems regarding consultation with the public." The IJC recommends "Give immediate priority to revitalizing public consultation activities in the AOC . . . with a view to generating and sustaining community understanding and support of the goals for AOC restoration." The IJC (1997b) [http://www.ijc.org/comm/21ste.htm] notes "U.S. and Canadian citizens have come to expect an opportunity to speak and to be heard . . . the parties will be challenged to develop and employ mechanisms that provide for meaningful public participation." Nowhere is this more true than in the ongoing RAP and LaMP implementation efforts.

The IJC (1997b) notes, "U.S. and Canadian citizens have come to expect an opportunity to speak and to be heard . . . the parties will be challenged to develop and employ mechanisms that provide for meaningful public participation."

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1997–99
Priorities Report
Chapter Four:

THE INDICATORS IMPLEMENTATION TASK FORCE

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4.1 INTRODUCTION

4.1.1 Background

In 1997, the Indicators Implementation Task Force (IITF) was established by the International Joint Commission (IJC) to investigate the feasibility of using indicators to monitor the progress of Canada and the U.S. (Parties) under the Great Lakes Water Quality Agreement (Agreement). The IITF work built upon the framework set forth by the Indicators for Evaluation Task Force (IETF) 1996 publication *Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement.*

1. Environmental indicators encompass a broad suite of measures, including tools for the assessment of chemical, physical and biological conditions and processes at several scales. In recognition of this fact, and as a framework for the IJC's indicators program, the IETF Report (1996) proposed "nine desired, positive outcomes to which the public and decision makers can relate and strive to achieve." (See Table 1.)

2. The Desired Outcomes incorporated the 14 beneficial uses listed in Annex 2 of the Agreement and are discussed in greater detail in Section 6.0 of this report.

3. For each of the Desired Outcomes studied, the IETF proposed indicators and measurements. According to the IETF (1996), measurements are primary data that provide the scientific basis to any conclusion in regard to achieving a Desired Outcome. Metadata are data about databases. Metadata describes the who, what, where, why and when of the data in each database.

4.1.2 Mission

The IITF is commissioned to:

- provide advice on the approach being developed by the Commission to obtain the required data and information to address the nine Desired Outcomes;
- provide a linkage between the Desired Outcomes and the development of priorities for the Commission's strategic plan; and
- investigate the feasibility of using indicators to monitor the Parties' progress under the Agreement.

Table 1 Desired Outcomes for the Great Lakes Basin Ecosystem (IETF 1996)

1. **Fishability**
   There shall be no restrictions on the human consumption of fish in the waters of the Great Lakes basin ecosystem as a result of anthropogenic (human) inputs of persistent toxic substances.

2. **Swimmability**
   No public bathing beaches closed as a result of human activities or, conversely, all beaches are open and available for public swimming.

3. **Drinkability**
   Treated drinking water is safe for human consumption; human activities do not result in application of consumption restrictions.

4. **Healthy Human Populations**
   Human populations in the Great Lakes basin are healthy and free from acute illness associated with locally high levels of contaminants or chronic illness associated with long-term exposure to low levels of contaminants.

5. **Economic Viability**
   A regional economy that is viable, sustainable and provides adequate sustenance and dignity for the human population of the basin.

6. **Biological Community Integrity and Diversity**
   Maintenance of the ability of biological communities to function normally in the absence of severe environment stress (ecosystem health) and to cope with changes in environmental conditions which impose stress, i.e. to be able to maintain their processes of self-organization on an ongoing basis (ecological integrity). Maintenance of the diversity of biological communities, species and genetic variation within species.

7. **Virtual Elimination of Inputs of Persistent Toxic Substances**
   Virtual elimination of inputs of persistent toxic substances to the Great Lakes system.

8. **Absence of Excess Phosphorus**
   Absence of excess phosphorus entering the water as a result of human activity.

9. **Physical Environment Integrity**
   Land development and use compatible with maintaining aquatic habitat of a quantity and quality necessary and sufficient to sustain an endemic assemblage of fish and wildlife populations.

4.1.3 Definitions

The IJC uses the following definition for an *indicator*:

"An indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. An indicator is a sign or symptom that makes something known with a reasonable degree of certainty. An indicator reveals, gives evidence, and its significance extends beyond what is actually measured to a larger phenomenon of interest" (IETF, 1996).

The U.S. Intergovernmental Task Force on Monitoring Water Quality defined an *environmental indicator* as a:

"measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality" (ITFM as cited in IETF, 1996).

4.1.4 Guiding Principles

IITF suggests the following guidelines for the selection indicators.

1. Indicators must be definable in the same manner by all parties. They should be standardized, use accepted terminology easily understood by the public.

2. Indicators must include metrics that are measurable using accepted scientific techniques consistent and reasonable with the practices currently being carried out by those in natural resources fields.

3. Indicators must be selected with the assumption that there are hundreds of potential indicators that would be equally plausible. The selection of specific indicators represents a best attempt to select those that will adequately measure environmental health and the progress of programs toward this goal.

The main purpose of this activity was to identify databases and other sources of information that could be used to support the IETF proposed indicators program. A number of federal, state, provincial and local government agencies and other organizations provided information and data to support indicators for assessing and monitoring progress under the Great Lakes Water Quality Agreement (see Table 2).

Table 2 Key Agencies, Organizations and Partnerships

U.S. Federal	Canadian Federal	NGOs
Environmental Protection Agency	Environment Canada	The Nature Conservancy
U.S. Fish and Wildlife Service	Health Canada	The Audubon Society
U.S. Army Corps of Engineers		Ducks Unlimited
National Resource and Conservation Service		The National Wildlife Federation
Sea Grant Programs		The Natural Resources Defense Council

4.2 RESEARCH OF GREAT LAKES DATABASES

The IITF identified databases and other sources of information that could be used to support the proposed indicators program and task force findings. The task force encountered difficulties related to incompatible sampling protocols and different reporting formats used by agencies in the basin. Further, a lack of uniform data quality and gaps in sampling and analysis complicate progress. Surveillance and monitoring activities differ across the basin and are not guided by clearly defined strategies.

There are temporal and spatial gaps in the data supporting indicators and measurements. For example, data for the 11 critical persistent toxic substances are uneven and site specific. Gaps are also present in data documentation, or metadata.

To solve this problem, for example, selecting indicators from the Desired Outcome Biological Community Integrity and Diversity, indicators and accompanying measurements would be facilitated by clearly defining their scope, developing definitions, and reaching consensus on definitions for the terms *Integrity* and *Diversity*.

4.3 OTHER INITIATIVES USING INDICATORS

The development of indicators is difficult and highly complex, a consensus supported by the IITF and others working on similar projects, such as the EU, EC and EPA. Many monitoring programs fail because operational issues, such as data management and information transfer are not adequately addressed. As well, some concepts, such as ecosystem management are constantly being redefined. Regular monitoring and long-term funding are essential. Updating the indicators and accompanying measurements is also essential as new issues emerge.

Many governmental jurisdictions are faced with similar environmental issues, many of which cross political boundaries. Collaboration through strategic partnerships should become the norm. As the IJC has stated multi-jurisdictional agencies are playing an increasingly critical role in the coordination of efforts within the Great Lakes basin.

To advance inter-agency communication and cooperation, there is a need for an acceptable indicator framework (see Table 3) to guide local decision makers, and to provide a common language, based on clear terminology and concepts. It is important for the IJC to be aware of how other multinational agencies are implementing indicators to ensure compatibility. As well, detailed and location-specific indicators are also needed to reflect unique regional conditions and the needs of local decision makers.

4.3.1 OECD

In 1993, the Organization for Economic Cooperation and Development, an agency of the EU, developed a core set of indicators for environmental performance reviews. Their work is set within a pressure-state-response framework that serves to structure and classify types of indicators, similar to the approach taken by State-of-the-Lakes Ecosystem Conference (SOLEC). In this model, *pressure* refers to stresses from human activities on the environment, *state* reflects the present conditions in an ecosystem and *response* deals with society's efforts to tackle environmental problems caused by pressures so that a feedback mechanism is enacted.

This core set of indicators is meant to form a common link to all OECD member nations and allow for cross-country comparisons. These are generally supplemented by more detailed, country-specific indicators that reflect the unique conditions of each region and the needs of decision-makers.

4.3.2 NAFTA and the CEC

The tri-lateral "North American Free Trade Agreement" (NAFTA), signed by Canada, the United States and Mexico in 1994, was supplemented by the North American Agreement on Environmental Cooperation (NAAEC), entered into that same year. The Commission for Environmental Cooperation (CEC) was subsequently created to administer this side accord. The CEC primarily achieves its mandate through information exchange, consulting services, and by fostering the development of new strategies for dealing with issues affecting the continent.

Two primary components of multinational environmental cooperation were identified (CEC, 1997):

a. Respect for each nation's sovereignty in establishing priorities, policies and legal frameworks that suit the needs of each country.

b. The importance of coordinated efforts in resolving shared environmental problems.

Each country maintains its own environmental regulatory framework while agreeing to collaborate tri-laterally in support of achieving sustainable development for all three nations.

The CEC designed a framework to assess the effects of NAFTA on the North American environment (CEC, 1999). This framework will:

- develop an understanding of the connections between trade and the environment;
- assist in anticipating important environmental impacts in the context of trade liberalization; and
- develop policy tools to better mitigate negative impacts and maximize positive ones.

As with many of the other initiatives reviewed in this report, the CEC recognizes the importance of assessing pressures on the environment (e.g. pollution). The CEC also refers to "environmental supports", such as waste management practices, which mitigate pressures and which may be created through government policies.

4.3.3 GPI

The Genuine Progress Index was developed in 1995 by StatsCan as an holistic measure of progress integrating social, economic and environmental variables (GPI Atlantic, 1998a). In 1997, Nova Scotia was chosen by Statistics Canada for a pilot project in which they adapted the original concept to reflect local

conditions and to emphasize policy applications and relevance. This work demonstrates an acknowledgment that the traditional measure of progress, based upon the Gross Domestic Product, is inadequate to address the importance of sustainable development. It is widely accepted that "new indicators of progress are urgently needed to guide our society: ones that include the presently unpriced value of natural and societal capital in addition to the value of conventionally measured economic production . . . the GPI is an important step in this direction" (GPI Atlantic, 1998a).

The Nova Scotia GPI is based upon social, economic and environmental indicators selected to reflect community well being and prosperity and to determine progress toward sustainability. The index will be developed by integrating the trends over the last 25 years with existing market statistics to construct an overall index of sustainable development for the province. The GPI is expected to be released in 2000 (GPI Atlantic, 1998b).

4.3.4 The State of Ohio 1998 State of the Lake Report: Lake Erie Quality Index

The Ohio Lake Erie Commission evaluated 28 aspects of the status of Lake Erie using 10 indicators and 28 metrics (measurements). The framework used existing databases and looked for short and long term trends. The three main objectives were to:

1. determine what is essential to know about Lake Erie;
2. design and implement effective measuring systems for these essential factors; and
3. establish goals and scoring systems that will allow for critical evaluation of progress.

Unlike most of the similar initiatives, this report and its indicators were intended for the public and, therefore, designed using straightforward terms and easily understood references. Three "themes" or areas of focus were used to set the context for the report, shown in Table 3.

It is widely accepted that "new indicators of progress are urgently needed to guide our society: ones that include the presently unpriced value of natural and societal capital in addition to the value of conventionally measured economic production . . . the GPI is an important step in this direction." (GPI Atlantic, 1998a)

Table 3 Framework for the Lake Erie Quality Index (OLEC, 1998)

	Theme	*Indicators*
1.	Environment	1) Water quality 2) Pollution sources 3) Habitat 4) Biological
2.	Recreational Resources	5) Coastal recreation 6) Fishing 7) Boating 8) Beaches
3.	Derived Economy	9) Tourism 10) Shipping

Scores for individual metrics were weighted according to importance, then tallied to produce a descriptive rating for the overall indicators.

For example, to assess the rating for water quality, the following five metrics were used: toxic contamination, contaminated sediments, bacterial pollution, drinking water, and water clarity.

These metrics were averaged to get the overall rating of "Good" for the indicator water quality. The Ohio Lake Erie Commission views this endeavor as a starting point of monitoring and restoration efforts. Metrics and indicators must be constantly reviewed and updated if information is to be kept relevant for the Ohio public.

4.3.5 Results of Review of Other Initiatives

In reviewing the process and progress of each of these indicator initiatives, the IITF notes that they reinforce our own findings and that they have been incorporated into the IITF work.

- Collaboration must become the norm to allow for real improvement.
- An internationally supported framework is needed to provide a common language and to promote inter-agency communication.
- Indicators must be necessary and sufficient to portray a state of the system.
- Indicators must be tied to specific goals and objectives.
- Indicators must be continually monitored and updated as new issues emerge.
- Managing databases in an efficient and standard manner is critical.
- Frameworks need to be geared to policymakers and the public at large.
- Indicators must be placed within a proper context, otherwise misinterpretation may occur.

Building on these findings, the IITF is adopting the IETF '96 proposed framework accordingly and collaborating with the Parties through SOLEC.

4.4 OTHER TASK FORCE ACTIVITIES

4.4.1 Workshop on Indicators of Integrity and Diversity of the Great Lakes Basin Ecosystem

According to Angermeier and Karr (1994), the terms *biological integrity* and *biological diversity* are widely used by the media, citizens, policymakers and some biologists without adequate attention to the concepts they embody. For the IITF, which is tackling the even larger concepts of *ecosystem integrity* and *ecosystem diversity*, this lack of attention must be addressed.

Both ecosystem integrity and ecosystem diversity are strictly scale-dependent concepts. This workshop, which used an ecological rationality, focus was on integrity and diversity at the scale of the entirety of the Great Lakes ecosystem as defined by various criteria for observation. There is an urgent need to entify the Great Lakes ecosystem by these explicit criteria, and by others, to define *ecosystem integrity* and *ecosystem diversity* within each of those logical types of description. Defining integrity and diversity for the Great Lakes ecosystem is a step that must be taken before headway toward those ideals may be measured using indicators. Progress on the development of indicators to describe the Desired Outcomes *Physical Environment Integrity* and *Biological Community Integrity and Diversity* requires a better understanding of the various types of ecosystems, as that understanding will give a particular meaning to the terms *ecosystem integrity* and *ecosystem diversity*.

Aided by six preliminary presentations and by a commentary from IJC Commissioner Susan Bayh, the workshop participants proposed many potential indicators of integrity and diversity. However, as with previous attempts to devise environmental indicators, the group noted that the data for the indicators ranged in state of consolidation, from a high level to no decision on even the parameters for determining what information needs to be collected. The participants concluded that the following questions should be used to scrutinize the utility of each prospective indicators.

- Is the indicator measurable? If so, what is the measurement and its unit?
- Does the indicator characterize the Great Lakes Basin Ecosystem in its entirety?
- If the indicator is a surrogate for direct measurement, is there a body of knowledge that supports its relationship to integrity or diversity? Participants observed that most of the listed indicators were surrogate measures of diversity as opposed to direct measures of diversity.

4.4.2 1998 Great Lakes-St. Lawrence Mayors' Conference

At this conference, the IJC emphasized the need for coordination among the IITF and SOLEC initiatives. The IJC needs information to indicate progress toward the general goals outlined in the Agreement and the IETF framework provides a useful tool to organize this information. Since an increasing amount of the information base for this framework is being, or has been, shifted to the municipal/local government levels, there is an even greater need for coordination and for formation of non-traditional partnerships to collectively measure progress under the Agreement.

4.4.3 State-of-the-Lake Ecosystem Conference, 1998. IITF Breakout Session on Implementing Indicators

During this session the IITF suggested the indicators: *PCBs in Lake Trout*, which supports both the *Fishability* and *Virtual Elimination of PTS* Desired Outcomes, and *Boil-Water Orders*, which supports the *Drinkability* Desired Outcome. These two indicators were used because they represent, respectively, indicators for which data are primarily collected at the provincial/state and federal levels of government, and indicators for which the data are collected locally.

Participants were asked to identify the tasks involved in developing an indicator in the Great Lakes basin. Participants were asked not to debate the merits of the two indicators but, instead, were to treat them as though they had been adopted by the IJC and were to be implemented.

General observations from the SOLEC '98 session.

1. An indicator must be responsive to public needs.
2. The Desired Outcomes should be better communicated to the public.
3. The matter of scale is important. The loss of specific information in basin-wide reporting is significant as many issues are highly relevant to local populations. The public makes decisions (i.e. Can I drink the water? Eat the fish?) that are based on information about local conditions.
4. Tension exists between the "top-down" and "bottom-up" approaches to selecting indicators (i.e. basin versus local).
5. Agencies have ownership of the data they collect. However, lateral and vertical information transfer needs to be encouraged.
6. The IJC indicators must be compatible with those of SOLEC.

7. Panels of experts should be assembled to further progress on measurement and interpretation of proposed indicators.

Participants recommend that SOLEC be used as a forum to develop further approaches to developing indicators, since implementation will be the responsibility of the Parties.

4.4.4 Technical Review of the June and October 1998 and May 1999 SOLEC Draft Reports

The IITF review of the above documents contributed to the modification of the SOLEC indicators database, allowing it to be sorted by the IETF proposed Desired Outcomes and by the annexes of the Agreement. In addition, the IITF sent its progress report to SOLEC including its Catalogue of Great Lakes Databases. SOLEC provided both personnel and money to support and further the work of the IJC. The compatibility of the two indicator efforts is highlighted by the potential for the development of common measurements that could then be used to support indicator efforts of both SOLEC and the IJC.

The SOLEC organizers have used IITF documents as a major source for the compilation of the SOLEC indicators for Great Lakes Basin Ecosystem Health. As well, the IITF Catalogue of Great Lakes Databases has become a unique resource and a valuable addition to the databases which support SOLEC indicators.

4.4.5 The International Association for Great Lakes Research Conference, 1998 and 1999

At the 1998 conference in Hamilton, Ontario, the IITF presented a paper entitled *Pilot Study Experiences for Implementing Indicators of Ecosystem Integrity in the Great Lakes Basin.*

In 1999, the IITF presentation Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement focused on the challenges associated with achieving consensus on a suite of indicators, measurements and reporting formats by highlighting three Desired Outcomes: *Swimmability, Fishability* and *Drinkability* and the relationship of IITF to the SOLEC process. The need for more co-ordinated data gathering activities in the Great Lakes basin was underlined, and focused workshops co-sponsored by SOLEC was discussed as a means of working toward indicators implementation.

4.4.6 Great Lakes Commission Online GIS Workshop

Members of the IITF participated in this conference because of its relevance to implementing indicators in the Great Lakes and to potentially co-sponsoring a Geographical Information Systems (GIS) Congress related to use of Geographical Information Systems in managing, analyzing and visualizing indicators databases.
The workshop assembled GIS experts to provide guidance to the Great Lakes Commission in initiating a new project entitled Great Lakes GIS Online. The project's goal is to develop a spatial data library for the Great Lakes and to provide timely access to this information by providing the information over the Internet via the Great Lakes Information Network. If successful, this project could provide a vehicle by which the Parties can share their data with the Great Lakes community and the world.

Working sessions covered topics including: consistent coverages and data production; data access, data sharing and data limitations; visualizing Great Lakes ecosystems; and collaborative initiatives. The need for planning and coordination among all participating organizations has to occur prior to collecting data and building the database and analysis system. This process is consistent with the recommendations of the task force in this area. Some other messages included good quality assurance/ quality control for data and good metadata are essential; always define the questions and the audience before beginning; and involve and receive buy-in from policy makers at beginning of the project.

The SOLEC organizers have used IITF documents as a major source for the compilation of the SOLEC indicators for Great Lakes Basin Ecosystem Health. As well, the IITF Catalogue of Great Lakes Databases has become a unique resource and a valuable addition to the databases which support SOLEC indicators.

4.5 RELATIONSHIP WITH SOLEC

The IITF review of the SOLEC indicator suite and IJC participation in the 1998 conference helped the SOLEC steering committee focus greater attention on the Agreement. SOLEC has now cross-referenced its indicators against the 14 impairments of beneficial uses from Annex 2 of the Agreement against the IJC Desired Outcomes, all of the other Annexes; pressure, state and human activity; Great Lakes Fishery Commission fish community objectives; environmental compartments, such as air, land and water; and against issues such as nutrients, toxic chemicals and non-native species. In addition, SOLEC has modified a pair of indicators that address concerns raised by the IITF review of earlier SOLEC documents. These new indicators are for the Desired Outcomes *Fishability* and *Drinkability*. As of May 1999, SOLEC has referenced or drafted an ecosystem objective/Desired Outcome for the majority of the proposed indicators. The results demonstrate a clear connection between the IJC work and that of SOLEC, tying them both to the purpose of the Agreement.

It is important that the IJC continue to influence the SOLEC development of indicators.

4.6 DESIRED OUTCOMES AND INDICATORS

The task force examined in detail the Desired Outcomes and indicators proposed by the IETF and considered how these could be implemented. As well, the IITF compared the IETF proposed suite of indicators with the SOLEC suite, as follows:

4.6.1 Swimmability

IJC Desired Outcome:
No public bathing beaches closed as a result of human activities or, conversely, all beaches are open and available for public swimming (IETF, 1996).

IITF Recommended Indicator:
Trends in number of beaches posted/closed because water posed a human health risk over a predetermined swimming season.

SOLEC Ecosystem Objective:
Waters should be safe for recreational use. Waters used for recreational activities involving body contact should be substantially free from pathogens, including bacteria, parasites and viruses that may harm human health.

Related SOLEC Indicators:
Fecal Pollution Levels of Nearshore Recreational Waters (ID: 4081). Measurements: 1) Counts of Fecal Coliform and/or E. Coli in Recreational Waters and 2) Frequency of Beach Closings at Specific Locations.

Local governments are responsible for beach postings and closings. Such decisions have significant repercussions on a community as the result of lost revenue from tourism and recreational activities, negative public perception regarding the quality of water, and direct costs of closing the beach. Beaches are closed for a number of reasons, not all of which are quantifiable. Professional judgement plays a significant role in decisions made about the swimmability of local water bodies. For example, beaches may be routinely closed after a period of heavy rainfall in anticipation of water quality problems. Thus, in order to answer the question "Can I swim in the water?" it is necessary to incorporate a level of flexibility into the indicator definition.

The 1992 Ontario Beach Management Protocol recommends beach postings where there is evidence "that the beach water poses a risk to the health of bathers." The evidence of potential danger may be based on bacteriological analysis, historical and epidemiological data, or the physical quality of the water. Reasons for beach postings may include:

- unacceptable results from bacteriological tests;
- outbreak of infectious disease in the community;
- presence of hazardous or infectious material, (such as medical waste);

- high water temperatures;
- pH outside the range 6.5-8.5;
- water clarity reductions; and
- any visible blue-green algae.

In the U.S.A., beach monitoring documents are issued by EPA, the National Resources Defense Council and by each state. In both countries, monitoring is the responsibility of local agencies. In May 1999, EPA announced the results of its 1998 survey of 1,400 beaches nation-wide based on a survey of 300 mostly local or regional agencies. Results of the 1999 survey will be on the EPA Beach Watch web site.

In the opinion of the IITF, the recommended indicator and the related SOLEC indicator and measurements are now compatible.

Several questions need further consideration.

- Does the definition of "beaches" include all recreational beaches in the Great Lakes basin including inland lakes, regardless of water body size?

- Over what time period will beach closings be measured, given spatial and temporal variability of the swimming season?

- Should beach posting, as opposed to beach closing, data also be tracked?

The IITF and SOLEC are participating in a workshop for the fall of 1999 to resolve these and other questions.

4.6.2 Fishability or Fish Safe for Human Consumption

IJC Desired Outcome:
There shall be no restrictions on the human consumption of fish in the waters of the Great Lakes basin ecosystem as a result of anthropogenic (human) inputs of persistent toxic substances (IETF, 1996).

IITF Recommended Indicator:
Fish consumption advisories.
Measurement: Number of added, altered, or lifted advisories, by Great Lake, and by Great Lake sub-basin.

SOLEC Ecosystem Objective:
Fish should be safe to eat

SOLEC advocates as an endpoint, the elimination of fish consumption advisories in the Great Lakes.

Related SOLEC indicators:
1. *Contaminants in Recreational Fish (ID:113); and*
2. *Chemical Contaminants in Fish Tissue (ID:4083).*

The term Fishability is misleading. It mistakenly implies that the ability to catch Great Lakes fish is under consideration. Therefore, the Desired Outcome should be renamed "Fish Safe for Human Consumption."

Fish consumption advisories are issued by all Great Lakes state and provincial governments. In addition, U.S. EPA has recommended "Fish Consumption Advisories" as an indicator for its own work. The U.S. EPA supports a comprehensive database that contains information about both Canadian and American fish consumption advisories.

Certain issues confound the development of this indicator, including:

- Criteria to define fish advisories and sampling protocols to collect data to support them vary among jurisdictions. Until a common set of protocols and criteria are implemented basin-wide, there will be inequities in comparing progress among lakes or sub-basins.
- A limited number of chemicals are routinely measured (e.g. PCBs, dioxin, lead, mercury). This limited analysis may miss other harmful compounds. For example, the potent liver toxin Microcystin is a serious problem in Lake Erie.
- A limited number of fish species are routinely monitored for contaminants.
- A limited number of samples per fish species are routinely monitored for contaminants.
- Human populations are exposed to different levels of risk from eating Great Lakes fish (i.e. women of child-bearing age and children are more susceptible to health threats caused by eating contaminated Great Lakes fish, as are high consumers of Great Lakes fish).
- The communication of fish consumption advisory information to the public (particularly non-anglophones and low-income populations) is inadequate.
- Over the course of a year, fish consumption advisories are added, altered and withdrawn making them difficult to count in a given jurisdiction.
- Compatibility of IJC indicator with those proposed by SOLEC (May 1999).

The term Fishability is misleading. It mistakenly implies that the ability to catch Great Lakes fish is under consideration. Therefore, the Desired Outcome should be renamed "Fish Safe for Human Consumption."

The adoption of a basinwide indicator would improve communication of fish consumption advisories to the public, and the coordination of sampling protocols and criteria.

These issues will be addressed during an IITF/SOLEC expert panel workshop scheduled for the autumn of 1999.

4.6.3 Drinkability

IJC Desired Outcome:
Treated drinking water is safe for human consumption; human activities do not result in application of consumption restrictions (IETF, 1996).

IITF Recommended Indicators:
1. *Trends in the number of exceedences of established drinking water standards; and*
2. *Trends in the number of drinking water restrictions.*

SOLEC Ecosystem Objective:
Treated drinking water supplies should be safe to drink.

Related SOLEC Indicator:
Drinking Water Quality (ID:4175) features trends in contaminant levels in raw, treated and distributed water.

There are a number of issues yet to be addressed:

Current Monitoring Programs: The limitations of current drinking water databases, in both Canada and the U.S., need to be examined. Privatization of water treatment may further exacerbate difficulties in both monitoring and reporting. The Ontario Drinking Water Water Information System contains water quality data collected through the Drinking Water Surveillance Program (DWSP) and the Water Inspections Program. DWSP monitors water quality 2-6 times per year based on source water type. Thms are monitored quarterly. DWSP monitors at least as frequently as the operating authories of the water supply systems are required under the Ontario Drinking Water Objectives (MOE, revised 1994). There is no organized water quality monitoring program for private (often groundwater) supplies. The U.S. Federal Safe Drinking Water Information System (SDWIS/FED) is not currently a fully reliable source of information. In 1998, the U.S. EPA acknowledged that "it had serious data problems after finding that 16% of violations in 1996 were missing from the database".

Raw versus Finished Water Quality: Drinking water quality is a function of: raw water quality; the capability of the treatment plant to clean the water; and, the state of the water distribution infrastructure. If any of these parameters is substandard, drinking water problems usually result.

Raw water quality is directly linked to water quality at the tap: Even well-managed water treatment plants can release chemical and/or microbial contaminants into the distribution system. Poorly maintained and aging distribution systems contaminate drinking water supplies due to the introduction of untreated water from outside the conduit. Thus, indicators are needed that reflect these various stages of drinking water treatment and delivery. Public concern about drinking water quality is high, and a significant proportion of the population has responded by installing point-of-use devices and by using bottled water.

Sources of Raw Water: Groundwater versus Surface Water: Approximately one-half of the Great Lakes Basin population uses groundwater for its potable water supply. There are also many water supply systems within the Great Lakes watershed that use surface water supplies that are tributary to the lakes themselves. Private groundwater systems are not monitored as closely as large water utilities that take water from surface or groundwater. Many rural households drink groundwater with little or no treatment.

Drinking water quality is a function of: raw water quality; the capability of the treatment plant to clean the water; and, the state of the water distribution infrastructure. If any of these parameters is substandard, drinking water problems usually result.

Raw Water Turbidity: Throughout North America, water treatment plants keep records of the turbidity of their raw water. Turbidity is measured in nephelometric turbidity units (NTUs) which relate to how light is scattered in water. This parameter is sampled frequently each day or continuously, with in-line turbidity meters, to meet U.S. and Canadian drinking water requirements (under the Safe Drinking Water Act, commonly known as the "Surface Water Treatment Rule" in the U.S.). It is intrinsically related to every water treatment plant daily operating procedures. The information is plant-specific, but may also be found, albeit for more limited sampling periods, in the Ontario DWSP database.

Several studies show a strong correlation between turbidity levels and significant cost increases for treatment, as well as chemical (pesticides and nutrients), disinfection by-products (THMs) and microbiological contamination of finished drinking water. Waterborne disease outbreaks are often found to be associated with increased raw water turbidity (e.g. Milwaukee, 1993). The Thunder Bay Post (MacDonald, 1998) reported that it would cost the city approximately $1.5 million to install chlorine dioxide treatment to combat its problems with *Giardia* and *Cryptosporidium*. The estimated cost of installing microfiltration was $56 million with a five-month installation waiting period.

While treated (or finished) water turbidity is information that must be reported to the U.S. EPA by each body with primacy for all of their water treatment plants, they are not required to report information about raw water turbidity. Therefore, this information is found either at the plant level or in the plant monthly reports to the agency with primacy.

These issues are on the agenda for the IITF/SOLEC workshop in August 1999.

Therefore, the IITF recommends that:

The IJC use these three Desired Outcomes and indicators for its 10th Biennial Report, and subsequent reporting cycles.

4.6.4 Healthy Human Populations

This Desired Outcome is still under review by the IITF and the IJC Health Professionals Task Force and the International Air Quality Advisory Board. SOLEC has incorporated the IITF and IETF recommended indicators for this Desired Outcome into the SOLEC Report (May 1999). The IITF will have a recommendation in its final report for December 1999.

4.6.5 Economic Viability

This Desired Outcome will not be researched by the IITF as agreed by the IJC in October 1998. However, significant work is underway in national and binational arenas, e.g. the GPI is being tested by StatsCan as a measure of economic and environmental activities in Nova Scotia (see Section 3.3).

The following IJC Desired Outcomes have not yet been thoroughly reviewed and considered by the IITF. This is work to be completed by December 1999. However, there have been some indicators and measurements investigated as outlined below.

4.6.6 Biological Community Integrity and Diversity

There are several indicators (and measurements) that have potential for use with this Desired Outcome, for example: PCBs in lake trout, mercury levels in sport fish, and concentrations of PTS in top predator fish and fish-eating birds.

As well, indicators for several other Desired Outcomes (e.g. Quality and Quantity of Wetlands for Physical Environment Integrity) will be useful.

A number of databases that contain relevant information about this topic have been identified. However, the sampling techniques, monitoring frequencies and geographic coverage vary significantly between databases.

In addition, SOLEC '98 is considering at least 26 indicators with potential to apply to this Desired Outcome.

4.6.7 Virtual Elimination of Inputs of Persistent Toxic Substances

Again, there are many indicators nominated by the IETF (1996) and SOLEC '98, which apply to this Desired Outcome.

There is a major question yet to be addressed, i.e. "what are the specific chemicals to be considered?" Should a focus be on the 23 persistent toxic substances groups listed in Annex 7 of the Agreement, or should the list be reduced, or expanded?

4.6.8 Absence of Excess Phosphorus

Desired Outcome:
Absence of excess phosphorus entering the water as a result of human activity.

Significant scientific studies have changed the understanding of phosphorus dynamics in large freshwater lakes. The IITF proposes that this Desired Outcome be changed to **"Return to a Nutrient-Balanced State."**

As well, new indicators and measurements reflect these changes:

- Hypolimnetic oxygen levels;
- Extent of temporal/spatial coverage of undersirable/ harmful algal blooms; and
- Amount of nearshore submerged vegetation.

Extent of Temporal/Spatial Coverage of Undesirable/ Harmful Algal Blooms

Undesirable/harmful algal blooms are a problem in the Great Lakes. The Rondeau Bay, Ontario area, appears to have *"persistent annual problems (July-September) with excessive Cladophera growth and fouling."* The Lake Erie LaMP (1998) recently reported the following about *Microcystis*:

"Between 1995-1998 Microcystis bloom appeared during the late summer and fall, in the western and central basins. Microcystis is a blue-green algae which can be described as a "thick slick of grass-green paint"."

The presence of *Cladophera* and blue-green algae are also associated with a degradation of the aesthetics of the Great Lakes. In addition, *Microcystin* is a potent liver toxic (Lake Erie LaMP, 1998).

Some water quality databases, such as EC's STAR database, do contain information about algae. The STAR database uses a scale from 0-4 to rank floating alga samples. This ranking scale, and the amount of data on this subject that are contained in the database, needs to be examined further.

According to Dolan (1998, personal communication), current information about undesirable algal blooms in the Great Lakes is, for the most part, study-specific. Although detailed information does exist for certain areas of the Lakes, much more information is in the form of anecdotal reports from people on the Lakes. Some field stations have information about the presence/absence of algal blooms. Unless these phenomena are within the research mandate of the station, it may not have more specific information about them (i.e. temporal/spatial data).

Information about harmful algal growths could be collected by aerial or satellite surveillance of the Lakes. The ground-truthing and updating of this record would require a substantial investment of time and money (Dolan, 1998, personal communication).

4.6.9 Physical Environment Integrity

Desired Outcome:
Land development and use compatible with maintaining aquatic habitat of a quantity and quality necessary and sufficient to sustain an endemic assemblage of fish and wildlife populations.

There are five indicators proposed by the IETF for this Desired Outcome. Additionally, SOLEC '98 has nominated at least 26 indicators which would serve this Desired Outcome.

The IITF proposes that three specific indicators modified from the IETF list should be considered for IJC use. These are nominated because of relevance, many data to support and they integrate many other potential indicators and their measurements.

a. Quantity and Quality of Wetlands

Wetlands are among the most studied habitat types of the Great Lakes Basin. Although a significant amount of information about both Canadian and American wetlands is available, a consistent binational inventory of Great Lakes wetlands is required. There appears to be more information about the *quantity* of remaining wetlands than about the *quality* of those wetlands.

Recent compilations of information related to Great Lakes wetlands include:

- SOLEC '98 discussion paper by Chow-Fraser and Albert (1998) entitled "Coastal Wetland Ecosystems";
- Environment Canada (1995) "A Catalogue of Wetland Databases and Inventories for the Canadian Great Lakes Basin"; and
- Nature Conservancy of Canada (1998) on-line "Catalogue of Great Lakes Wetlands Information Resources".

In addition, non-governmental organizations, in particular Ducks Unlimited, have done much to promote and protect wetland habitats; there is much information and data available from these sources.

b. Quality and Quantity of Stream Base Flow

Surface water is usually hydraulically connected to groundwater, but the interactions are difficult to observe and measure and commonly have been ignored in water management decisions and policies. Most groundwater contamination caused by leaking petroleum storage tanks and hazardous waste disposal sites, attributed to agricultural fertilizers and pesticides, and to sewage pathogens and deicing compounds, is located in shallow aquifers that are directly connected to surface water. Therefore, groundwater can be a major and potentially long-term contributor to contamination of surface water. In some cases, surface water quality standards and criteria are unlikely to be met without reducing contaminant loads from groundwater discharges.

The amount of water that groundwater contributes to streams can be estimated by analyzing stream flow hydrographs to determine the groundwater component, which is termed "base flow" (Troyak, 1996). Withdrawing water from shallow aquifers near surface water bodies can diminish the available supply by capturing some of the groundwater flow that otherwise would have discharged to surface water. The quantity of groundwater withdrawn is approximately equal to the reduction in stream flow that is potentially available to downstream users. In landscapes that are relatively flat, drainage of land is a common practice preceding agricultural and urban development. Drainage is often accomplished by burying tile drains beneath the land surface, which can change the areal distribution of groundwater recharge and discharge. These changes ultimately affect stream base flow.

The USGS has water quality and stream flow datasets for 679 locations in the U.S. from 1962 to 1995, and for 618 stations from 1973 to 1995. In the Great Lakes Region, water quality and stream flow data are organized in separate station and parameter files. This data is readily available and can be easily accessed. Environment Canada also has such data. The web site where this information can be found is: http://wwwrvares.er.usgs.gov/wqn96/ .

The daily stream flow values for 54 U.S. streams for the 30-year period, 1962-1991, were used by the USGS for base flow analysis. An average of 52 percent of the stream flow was found to be contributed by groundwater. Base flow ranged from 14 percent to 90 percent, with a median of 55 percent. The Sturgeon River Basin in Michigan, which is underlain by highly permeable sand and gravel, has approximately 90 percent of its average annual flow contributed by groundwater. Other USGS data estimate that the groundwater contribution to total tributary flow averages 45 percent in the Lake Erie Basin and averages 62 percent in the Lake Huron Basin.

c. Number and Extent of Engineered Land/Water Interfaces

This indicator addresses two separate issues dealing with anthropocentric manipulation of shorelines and land/water interfaces, leading to changes in the dynamics of natural water flow.

The first issue encompasses "true" land/water interfaces such as wharfs, sheet piles, groynes and other engineered shoreline interfaces. A better understanding of the extent of these structures could lead to improved shoreline habitat protection.

The second issue deals with the increase in the amounts of impervious/hardened surfaces resulting from increasing urban density (e.g. roofs, airports, parking lots, roads, sidewalks, etc.) This spread of engineered interfaces has led to more artificial landscapes in which hardened surfaces lead to: enhanced runoff due to decreased water absorption into the ground, less groundwater recharge, reduced stream base flow, increased soil erosion, wider and straighter stream channels, and increased water temperatures and salinity, in turn leading to altered aquatic habitats (Reisman, 1999b). All of these impacts are attributable to *"serious hydrological disruption"* in which there is a reduction in *"the natural infiltration of rainfall and a great increase in the amount and rate of stormwater runoff"* (Reisman, 1999b).

4.6.10 Conclusions

General Findings

- Ample data are available to support the concept of Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement.
- The data are not of uniform quality and many gaps are apparent that may adversely impact the implementation of individual indicators.
- The wording of some proposed indicators need to be more clearly defined to help facilitate the data collection process.
- Many proposed indicators and measurements need refinement.
- The compilation of a Catalogue of Great Lakes Databases is a worthwhile initiative (Morrison 1999).
- There are a number of surveillance and monitoring activities currently taking place in the basin that are not guided by a coherent strategy.

These and other findings will be incorporated into the final IITF Report in late 1999.

Proposed Long Term Involvement by the Commission

The IITF recommends that the Commission dedicate resources to Indicators application, use and implementation over the next decade because:

- **SOLEC is proposing a staged implementation of indicators.**
- **Surveillance and monitoring programs will need to be modified and, in some cases, initiated.**
- **New and different partnerships (e.g. collaboration with muncipal and local governments and agencies) will develop.**
- **Information management and portrayal (i.e. GIS) will require more attention and organization (i.e. who does what?)**

The Commission should consider:

- **ensuring that indicators development continues to be an ongoing IJC priority;**
- **maintaining indicator development expertise and momentum by assigning this task to a staff member;**
- **working with the Council of Great Lakes Research Managers and the Science Advisory Board to identify and foster research needed to advance our understanding, interpretation and dissemination of indicators; and**
- **continuing to collaborate closely with the Parties to reach consensus on a common set of indicators for the Great Lakes, and to implement a binational, integrated monitoring program.**

Additionally, the IJC could:

- **convene biennially an expert workshop to update the IJC on international indicator initiatives and development.**
- **establish a standing work group to sustain the Commission's interests in indicators.**

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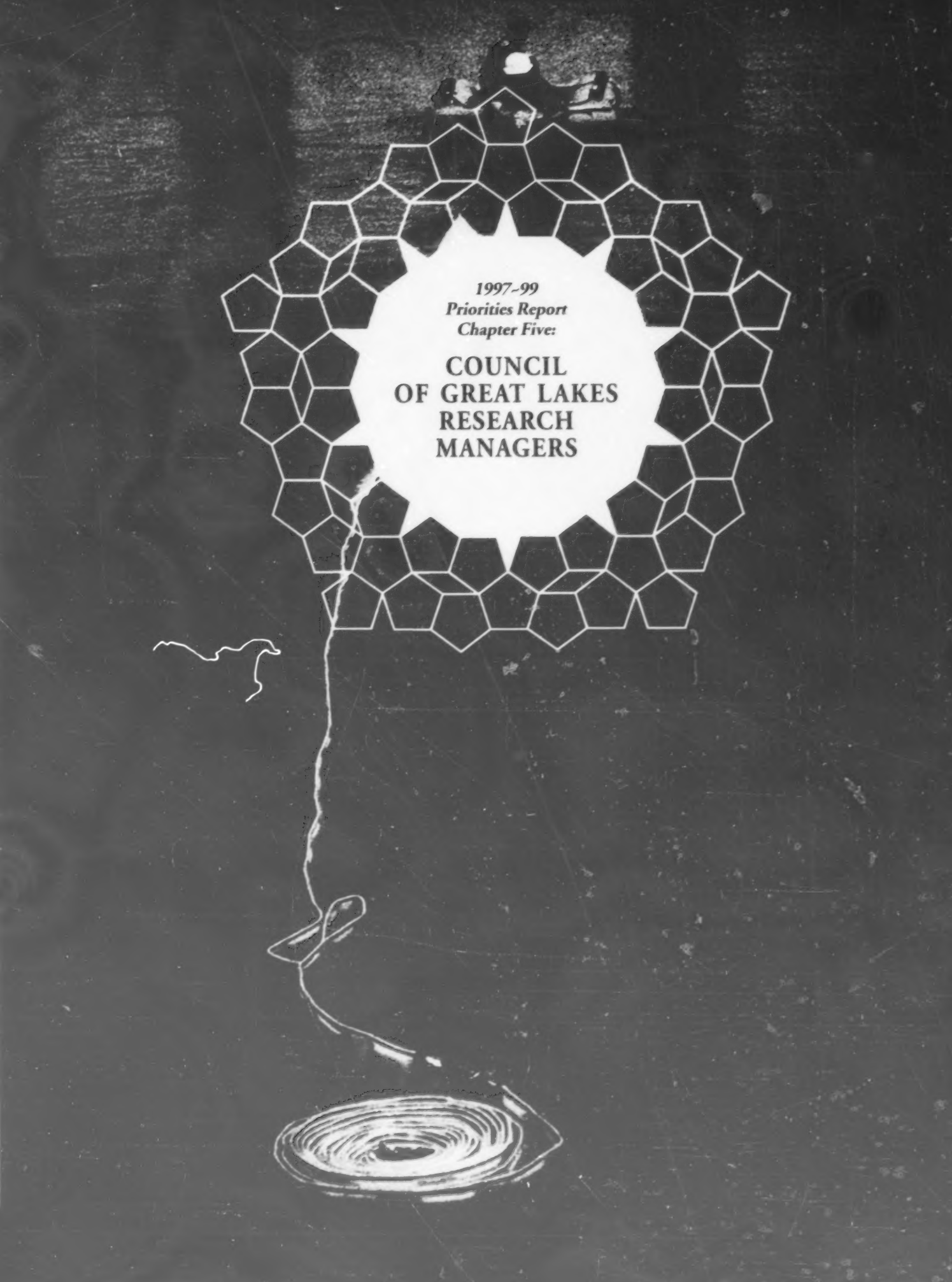

1997–99
Priorities Report
Chapter Five:

COUNCIL OF GREAT LAKES RESEARCH MANAGERS

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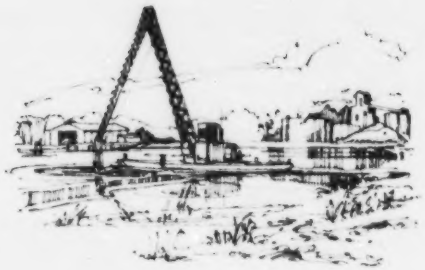
5.1 INTRODUCTION

The Council of Great Lakes Research Managers (the Council) is the International Joint Commission's (IJC) principal advisor on research programs and research needs. The Council undertook a number of activities in the 1997-99 biennial cycle, in accordance with identified priorities from the Commission. In addition, the Council scoped out a number of issues that will form the basis of future work by the Council, and advice to the IJC, and also supported some significant research activities.



5.1.1 Council Priorities

The Great Lakes-St. Lawrence Research Inventory continues to be the most frequently accessed area on the IJC's web site, often recording 500 hits per month. This venue coupled with increased conference exhibits at Great Lakes events has generated considerable exposure and greater inventory use by both the science community and the general public, use which is expected to continue in an upward trend.

Modeling Summit sessions were held at two major Great Lakes conferences. The first was held at the State of the Lakes Ecosystem Conference 1998 (SOLEC'98) in Buffalo, New York, and focused on the linkages amongst ecosystem components. The second was held at the International Association for Great Lakes Research 1999 (IAGLR'99) in Cleveland, Ohio and centered on the application of models to Lake Erie management issues.

As a founding member of the Task Team responsible for establishing the Great Lakes Communicator Network, the Council held an inaugural workshop in March 1999 in Ann Arbor, Michigan. The event was very successful and attended by communicators, managers, and scientists to develop a strategy for communicating research needs, gaps, and priorities using media, education, technology, and resource-sharing mechanisms.

5.1.2 Scoping Activities

At its 27th meeting in Niagara Falls, Ontario, in an effort to prioritize our efforts and better advise/serve the Commissioners, the Council defined an activity called "scoping" whereby the Council would evaluate the current state of knowledge and research needs, gaps and priorities for issues/problems facing the region, and evaluate their relevance to the IJC. During the 1997-1999 Priority Cycle this scoping activity was directed at seven IJC priority areas: sediment, indicators implementation, Lake Erie, commercial aquaculture, biodiversity and habitat, persistent toxic substances and endocrine disrupters, and Remedial Action Plan (RAP) and Lakewide Management Plan (LaMP) research. These are discussed more fully below.

The scoping of the biodiversity and habitat issue in particular, generated numerous recommendations from experts in support of preservation and enhancement. Additionally, a survey of 136 Great Lakes agencies and institutions was undertaken in June 1998 to gain a better understanding of organizational roles, responsibilities, and goals with a view to ensuring preservation of critical habitats, enhancing an ecosystem/ ecoregional management approach, developing effective legislation, and coordinating biodiversity research.

5.1.3 Research Support Activities

In addition to the Research Inventory, the Council's research support activities were targeted at research vessel coordination and the development of a formal relationship and joint initiatives with the International Association for Great Lakes Research (IAGLR). Research vessel coordination workshops were held in March 1998 and in February 1999, premised on previously generated recommendations. Topics explored included communication and information sharing, institutional information requirements, and program development/coordination.

Two motions of significance involving joint initiatives with IAGLR were passed at the Council's 30th meeting in Montreal. The first involved an annual donation of $1,000 used to conduct a survey of emerging research needs, and the second was aimed at engaging heads of major research laboratories/agencies in presenting their research activities, priorities, and future directions at each annual IAGLR conference.

5.2 COUNCIL PRIORITIES

5.2.1 Research Inventory

The Council of Great Lakes Research Managers, in an effort to promote inter-jurisdictional and interdisciplinary planning and coordination of research related to the implementation of the Great Lakes Water Quality Agreement, initiated this compilation of current research activities in the Great Lakes-St. Lawrence River basin. The Great Lakes-St. Lawrence Research Inventory continues to be produced by the Council every year as part of the continuing priority for improving the effectiveness and awareness of research throughout the Great Lakes region.

1997 Inventory

When compared to the 1996 inventory, fewer projects and dollars of research were represented in the Inventory for this year (290 projects and $39 million U.S. dollars). Part of the reason is a real decrease in research funding. However, another reason for the decline is that many managers and researchers are overworked and are continually being asked to do more with less, including managers who complete the project descriptions for the Inventory. Note that improvements were made by the addition of an update capability which allowed changes to project descriptions on-line without having to re-enter the entire project. Also, the mailing list was refined to avoid duplicate mailings.

1998 Inventory

The total number of projects entries increased to 436 representing a value of $67,219,112 US plus $ 6,489,145 Cdn. Forty-seven distinct agencies and organizations from both the U.S. and Canada had research projects listed in the inventory. Many of these agencies are further represented by branches, regions, and districts. Submitting agencies included government agencies, universities, Sea Grant extensions, Ontario conservation authorities, and associations.

A number of modifications were made to the 1998 Inventory following suggestions from the Council to increase the use of the Inventory for managing research and assessing information. These changes included more extensive searching capabilities, whereby it is now possible to search the inventory using ten different categories such as inventory titles, submitters, submitting agencies, keywords, investigators, scope, scale, type, state/province, and basin. The Research Inventory search page can be found at http://www.ijc.org/cglrm/ri99home.html(.)

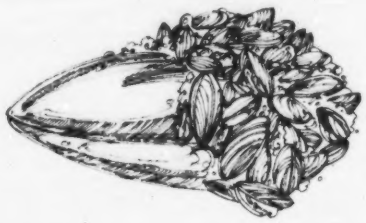
Two new sections were added to the request form to provide information for the Great Lakes Panel on Aquatic Nuisance Species and monitoring and research for the Lake Ontario Lakewide Management Plan (LaMP) Work Group. This survey is an efficient means of developing the Panel's inventory of aquatic nuisance species research relevant to the Great Lakes basin. The Great Lakes Panel anticipates that this research information will assist with future efforts to prevent further aquatic nuisance species introductions. The second addition to the form requests additional information details on monitoring and research relevant to Lake Ontario. Information regarding relevancy of research to beneficial use impairments, contaminant loadings or concentrations, and monitoring details such as media type, intensity, and monitoring region, will be used to guide future updates to LaMP documents.

Projects were accepted for the 1998 Research Inventory until March 15, 1999 at which time the 1998 database was closed and finalized.

1999 Inventory

A request for new submissions and update forms was sent out in early May of 1999 for inclusion in the 1999 Research Inventory database. Presently there are 316 projects in the 1999 Research Inventory with a value of $21,835,302 US plus $5,661,200 Cdn.

The Council's Research Inventories continue to be the most highly accessed publications on the IJC's web site, often recording more than 500 hits per month. An exhibit of the Research inventory was featured at the IAGLR'99 conference in Cleveland, Ohio and also at the 1999 IJC's Biennial Forum in September. Through these events, increased use of the Research Inventory by the science community and the public is expected.



In 1998 the total number of projects entries increased to 436 representing a value of $67,219,112 US plus $ 6,489,145 Cdn. Forty-seven distinct agencies and organizations from both the U.S. and Canada had research projects listed in the inventory.

5.2.2 Modeling Summit

Council activities under this priority consisted of two sessions held at major Great Lakes conferences during the priority cycle: SOLEC'98 and IAGLR'99. The title of the SOLEC'98 session was: "Connecting Ecosystem Objectives and Indicators through Modeling" and the IAGLR'99 session was called: "Great Lakes Modeling Summit: Focus on Lake Erie". A stand-alone report is planned for this priority, but a brief description and summary of the sessions is provided here.

SOLEC Modeling Summit, October 23, 1998

At SOLEC'98 held during October 1998 in Buffalo, New York, the Council hosted a modeling session focussing on connecting ecosystem objectives and indicators. This session presented two examples of how LaMP workgroups can use models to make a theoretical connection and validate the selection of an indicator of a given ecosystem objective that they have "set."

The Council defined the following terms for use during the workshop:

Environmental Indicator: A measurable feature or one derivable from measurements which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality, or reliable evidence of trends in quality.

Ecosystem Objective: A statement of a goal or desired outcome for a water body that describes in qualitative terms a target which management efforts are attempting to achieve.

Modeling: The exercise of representing a part of the ecosystem symbolically, either as a diagram or as a set of mathematical equations. Simple or conceptual models can be described in a drawing with boxes and arrows. Complex mathematical models are usually computer programs with mathematical and/or statistical descriptions of the system being modeled.

The achievement of an ecosystem objective is tracked by the selection and reporting of one or more indicators that quantitatively monitor ecosystem response. A good indicator of ecosystem health and integrity integrates a wide range of environmental factors (or stressors) into a single attribute that reflects the response of the system to those stressors. Ecosystem models that relate the response of an ecosystem to the cumulative impact of multiple stressors can provide the theoretical basis for indicator selection and application.

Starting from a couple of hypothetical ecosystem objectives (e.g., elimination of fish consumption advisories, absence of blue-green algal blooms, sustainable walleye population, etc.), an appropriate model was used to demonstrate the connection with each example to an indicator. One presentation used a mass balance/bioaccumulation model for Lake Ontario to demonstrate the quantitative relationship between a potential indicator, the concentration of PCBs in lake trout, and a potential action of the Lake Ontario LaMP, the reduction of PCB loading to the lake. In the other demonstration, an analysis of lakewide estimates of seasonal production and consumption by all pelagic trophic groups was presented. This analysis suggested that there was not enough production by alewife to support the energy demands of the salmonid community in Lake Ontario. Accordingly, a 50% reduction in salmonid stocking was recommended and subsequently implemented with the predicted effect of restoring the balance between piscivorous fish and their prey. After the presentation of these examples, the participants were asked to suggest their own favorite ecosystem objective and then "work" their way through how a model framework might help in the selection and theoretical justification of an indicator/s for that objective.

An examples was worked through to illustrate the process to the participants.

EXAMPLE:

Using control of phosphorus in Lake Erie as an example, the ecosystem objectives (from the GLWQA, Annex 3) are:

a. Restoration of year-round aerobic conditions in the bottom waters of the Centra Basin of Lake Erie; and

b. Substantial reduction in the present levels of algal biomass to a level below that of a nuisance condition in Lake Erie.

Mathematical models of algal growth and oxygen depletion in Lake Erie were developed to determine the quantitative relationship among the indicators phosphorus loading, summer average chlorophyll *a* and late-summer/early-fall hypolimnetic oxygen concentrations. The models then established a quantitative relationship between stressors and indicators as they related to the two ecosystem objectives, thus permitting the development of target phosphorus loadings for achieving those objectives. With the invasion of the zebra mussel in Lake Erie, new, more specific ecosystem objectives may be necessary.

RESULTS:

Key Questions: The following key questions were addressed at the workshop: 1. What ecosystem objectives are you interested in addressing? 2. For each ecosystem objective identified in 1. above, suggest an indicator. What data would need to be collected to allow reporting of that indicator? 3. Have you heard of a model or modeling approach that you wish to know more about? 4. What case studies can be described which have ecosystem objectives, indicators and models already in place?

Participant Perspectives: The participants were interested in knowing why models were needed to interpret indicators. Two examples were presented to show that indicators cannot be used in the absence of understanding. Models are successful in providing that understanding when the response variables are selected to coincide with the desired outcomes.

Session Outcomes: Models should be constructed in a way that allows new species to be handled. We have good models of various parts of the ecosystem, but we need to work on the linkages. For example, we need better linkages 1. among air, land and water; 2. between near-shore and offshore; and 3. between the upper and lower food chains in lakes. If these linkages can be achieved, models can help sort out competing multiple outcomes.

Next Steps: Models cost only 1 to 1.5% of what control actions cost. We need to better sell modeling as part of the tools of Great Lakes management. The suggested approach is to:

1. Provide examples of successful modeling in support of indicators;

2. Show how indicators can be misinterpreted in the absence of models;

3. Show how models can resolve conflicts among indicators;

4. Show how models can predict when indicators are likely to respond; and

5. Show how managers can be involved in defining desired outcomes for lakes.

IAGLR Modeling Summit (May 27-28, 1999)

The Summit was a continuing effort to bring modelers together with resource managers to discuss the application of models to management issues. This year, the focus was on Lake Erie. The Lake Erie at the Millennium Issues Workshop, held at the University of Windsor in November 1998, had identified 71 Lake Erie management issues that were grouped into six broad categories:

1. Eutrophication/Primary production
2. Exotic Species/Nuisance Aquatic Species
3. Upper Food Web Exploitation
4. Ecosystem Stability
5. Habitat Structure and Function
6. Contaminants

The Lake Erie Summit was held at Case Western Reserve University in Cleveland, Ohio. Invitees were each asked to prepare a 7-8 page white paper describing a model that would address as many of these issue categories as possible. The goal was to achieve a quantitative/predictive capability for the Lake Erie ecosystem. In other words, the Council was trying to assess the potential for models to help implement the "Ecosystem Approach to Management" for Lake Erie. In order to meet this challenge, each model, at a minimum, was to include the following state variables:

- nutrient concentrations
- total algal biomass
- blue-green algal biomass
- walleye biomass
- fish body burdens of bioaccumulative chemicals (*e.g.*, PCBs)
- zebra mussel biomass
- richness and evenness of the fish community trophic levels between algae and top predator fish

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Invitees were each asked to prepare a 7-8 page white paper describing a model that would address as many of (the) issue categories as possible. The goal was to achieve a quantitative/predictive capability for the Lake Erie ecosystem.

Further, the model should indicate which stressors control these variables and whether or not they were susceptible to management actions. The invitees were asked to state explicitly their perception of the management problem being addressed. Two groups of panelists provided comments and answered questions at the Summit.

Also, the white papers were to include modeling assumptions, data/monitoring/research needs, relevant space and time scales, and other constraints needed for describing the model. The white papers are available on the Web at: http://www.ijc.org/boards/cglr/modsum/index.html

RESULTS

Several areas of agreement were reached among the participating modelers:

1. Primary productivity must be better understood (ie. the bacterial component has been neglected);

2. Spatial gradients in Lake Erie are too important to ignore (ie. west to east and nearshore/offshore);

3. Better calibrations of models are needed (ie. verification should be conducted under radically different conditions;

4. Modeling approaches are complimentary (ie. duplication of effort is healthy for complex topics);

5. Current monitoring programs are not sufficient to support even the most modest of modeling projects (ie. there is no long-term commitment to monitoring);

6. Carbon budgets need to be refined to better account for zebra mussel impacts and the role of bacterial activity; and

7. Models themselves are principally pedagogic, and it is the experience and insight gained from building them, not precise model predictions, that outfit the scientist for helping managers.

There are still areas of disagreement among modelers:

1. What is the appropriate level of aggregation? (ie. Can we lump state variables across space and time?);

2. Uncertainty of the appropriate degree of emphasis on the lower foodchain vs. the upper foodchain (ie. time and space scales);

3. Uncertainty in the linkages across the foodchain (ie. zooplankton); and

4. Are zebra mussels limited by vertical transport of particulate matter?

The panelists also had points of agreement:

1. Diversity of approaches is good, but there is confusion on which way to proceed.

2. The benefits of modeling vs. the price tag needs to be articulated and resolved.

3. There is utility in having both predictive and diagnostic models.

Both the modelers and the panelists agreed that future plans should be made to hold a session in which modelers and managers collaborate to implement a solution to some pressing management problem.

The Council recommends:

- **Sufficient monitoring programs and coordinated research programs are essential to the development of modeling projects which can provide assistance to managers in addressing pressing management issues.**

5.2.3 Communication of Research Needs, Gaps, and Priorities

The Council discussed the importance of this issue and announced this effort in our address to the Commissioners in Niagara Falls. The Council is also one of the founding members of the Task Team to establish the Great Lakes Communicator Network. The goal was to develop and convene a Great Lakes Communicator's Network to address Great Lakes regional communications needs. The objectives of the inaugural workshop were to:

- Identify common issues and resources.
- Collaborate or develop partnerships on communications activities to develop more effective messages to be sure we are speaking with one voice when complex issues are discussed.
- Address educational awareness and product/program needs.
- Increase the effectiveness of Great Lakes communication efforts by sharing information on media projects, technology trends and traditional communications.
- Engage broader Great Lakes public in magnifying and expanding Great Lakes communication messages. Held in Ann Arbor, March 1999, approximately 40 agency communicators and resource managers/scientists exchanged perspectives on needs and actions.

A Great Lakes Communicators Listserve was established in March 1999, under the lead of the Great Lakes Commission. At the May 1999 IAGLR conference, the Great Lakes Communicators Network sponsored an interactive session featuring four panelists from a variety of backgrounds. Panelists shared their views on the challenges faced by media members and scientists when they interact on the reporting of a scientific issue. Session attendees had the opportunity to participate in lively discussion, and a follow up session for IJC Biennial Forum will be held in Milwaukee.

. . . pursue a media corner on GLIN to feature news on Great Lakes agencies. Reporters (and others) could visit this site to get a good sense of what's going on in the region, what upcoming events they should be covering, and different perspectives on a specific issue (e.g., the Lake Champlain controversy or Great Lakes diversions) from various agencies.

Summary of Suggested Next Steps for Action, based on the March 1999 workshop

Media:
- Create a mechanism to share media lists (i.e., a list of which Great Lakes communicators deal with which audiences).
- Create a Great Lakes Tip Sheet (Possibly a listserve through GLIN (The Great Lakes Information Network)).
- Pursue a media corner on GLIN to feature news on Great Lakes agencies. Reporters (and others) could visit this site to get a good sense of what's going on in the region, what upcoming events they should be covering, and different perspectives on a specific issue (e.g., the Lake Champlain controversy or Great Lakes diversions) from various agencies.

Education:
- Great Lakes Commission via GLIN and the Center for Great Lakes Environmental Education will work together to determine needs and define responsibility regarding development of an education website that could include an educational material list of items to be ordered or a resource list of on-line activities.
- Send the Council's education material to the Center for Great Lakes Environmental Education for distribution to teachers who call.
- Talk directly to teachers via the GLIN listserve set up for educators.
- Host summit of teachers to identify their educational needs.

Progress, look into the potential to:
- Survey teachers during the already planned teachers workshop during the Great Lakes Student Summit in Buffalo, New York, May 13-14, 1999.
- Use the information gained through the survey to create a workshop for teachers.

Technology
- Develop Communications Network listserve: com.net on GLINProgress.
- Develop a Multiserver search function on GLIN NetMeeting or other Internet conferencing.
- Review of clearinghouse proposal for the Great Lakes Environmental Education CenterVirtual Press Room on GLIN.

Sharing Resources
- Organize IAGLR panel discussion Progress on Communicating Science to the Media. This was completed and a mix of reporters and seasoned scientific communicators attended.
- Decide how often the Network should meet in terms of a conference.
- Discuss future funding avenues.

The Council suggested a number of potential subcommittees such as the following: Conferences/workshops; Electronic/web resources; Educational materials; Media outreach; Marketing; and Publications.

5.2.4 Biodiversity and Habitat

The Council conducted two activities with regard to this priority in the 1997-1999 Priorities Cycle. One was a "scoping" of the topic to identify research needs, gaps and priorities (See section III for a general description of scoping activities). The other activity was a survey of Great Lakes agencies and institutions regarding their goals for biodiversity and habitat. These activities are summarized below.

Scoping of the Biodiversity and Habitat Priority

The Council used the following sources of information to "scope" this priority: Great Lakes scientists; Government/private research programs; scientific literature; and the World Wide Web.

In general, the "scoping" resulted in this overview:

Biodiversity started as species cataloguing and has more recently emphasis has been placed on species assemblages and associated habitat. There are an extensive number of biodiversity and habitat initiatives underway. These initiatives range from well-funded, technically complex primary research, to regional surveys that depend largely on volunteer help from interested naturalists. Emphasis appears to be on large, showy, rare species and less emphasis has been placed on species such as non-vascular plants, insects, near shore crustaceans, algae, and microbes. An emerging issue for this topic is: How much, and what kind of habitat conservation is required to maximize biodiversity?

There are numerous examples of existing and on-going biodiversity and habitat programs including the following: atlases, biodiversity investment areas, the Ecological Monitoring and Assessment Network, the Aquatic Communities Classification System, the Great Lakes Fishery Commission's Fish Biodiversity Project, and the Great Lakes Fauna/biodiversity CD's from the University of Guelph.

Through "scoping" this priority the Council outlined in their recommendations the need to:

1. Clearly identify objectives for biodiversity and habitat initiatives;
2. Encourage and support the more recent ecoregional or ecosystem approach to habitat and biodiversity preservation;
3. Promote efforts on smaller organisms such as non-vascular plants, microbes, algae, insects, and crustaceans. In aquatic ecosystems these data are especially needed for near- shore habitats;
4. Support initiatives to link the various biodiversity/habitat programs so that the large quantity of data can be used in the most effective manner; and
5. Encourage the training of systematists to increase available expertise.

These initiatives range from well-funded, technically complex primary research, to regional surveys that depend largely on volunteer help from interested naturalists. Emphasis appears to be on large, showy, rare species and less emphasis has been placed on species such as non-vascular plants, insects, near shore crustaceans, algae, and microbes. An emerging issue for this topic is: How much, and what kind of habitat conservation is required to maximize biodiversity?

Survey of Biodiversity and Habitat Goals in the Great Lakes

This study was designed as a continuation of the initial "scoping" of the Biodiversity/Habitat Issues for the Great Lakes. Members of the Council wanted to develop a better understanding of the number and types of organizations involved in the preservation and enhancement of biodiversity and the relevant habitat issues and goals in the Great Lakes. To do this, the Council developed and distributed a survey. The survey's intent was to gain a better understanding of biodiversity and habitat goals of agencies working in the Great Lakes region and included:

- collecting information on which agencies were involved in gathering information on the current biodiversity research as well as habitat issues;
- defining what role these agencies were playing and whether it was a fundamental part of their organizational make up;
- defining what the agencies habitat goals are; and
- evaluating how the agencies were encouraging biodiversity when involved in habitat restoration or enhancement.

The survey was designed as primarily a yes/no response and choosing from a list of options as well as providing space for additions or comments. Respondents were also asked to provide any relevant documents or additional information as an attachment. A four page survey consisting of 17 questions was mailed to 136 agencies on June 26, 1998. Of these, 51 were Canadian and 85 were U.S. agencies. Due to the variety of organizations surveyed, not all survey questions were applicable to all surveyed organizations.

Agencies were chosen following an extensive search of the World Wide Web for organizations whose web pages had information about biodiversity as well as from an existing mailing list. Agencies surveyed included museums, colleges, universities, environmental and conservation organizations, foundations, funding agencies, government agencies, and research organizations.

The agencies chosen were a mere fraction of the numerous agencies and organizations involved in biodiversity and habitat in the Great Lakes-St. Lawrence area and as a result the agencies surveyed can not be viewed as a comprehensive list. A comprehensive literature search was also conducted on the World Wide Web in conjunction with the agency search to compile a reference bibliography of reports and current information available regarding biodiversity.

The Survey Results

The Council received 47 responses which represented approximately 35% of the 136 surveys requested. These include six responses from agencies that did not complete the survey as biodiversity was not within their scope or goals of their organization. These uncompleted surveys were not included in analysis (Table 1).

Table 1 **Types of Respondents to the Biodiversity Survey**

Category	Number of Respondents
Universities	10
Colleges	1
Environmental/ Conservation Organizations	9
Research Organizations	3
Corporations	2
Government Agencies	12

- Twenty-two of the agencies (26/42=62%) responded that they do have goals, policy objectives or a mandate regarding biodiversity goals.
- 24% of the respondents indicated that they were mandated by legislation for biodiversity. The Clean Water Act was another legislation mentioned by respondents.
- The majority of respondents use an ecosystem approach. 15 respondents use the ecosystem approach as compared to 5 that use ecoregion and 4 that use landscape approaches exclusively (Table 2). A number of other organizations use a combination of more than one approach.

Table 2 **Types of Approaches Used by Various Organizations**

Approach	Respondents
Ecosystem	15
Ecoregion	5
Landscape	4
Species or habitat type specific	3
Ecosystem and Ecoregion	1
Ecosystem and species or habitat	4
Ecosystem/Ecoregion and species or habitat type specific	2
Landscape and species of habitat	1
Ecosystem and landscape	1
Combination of ecosystem, ecoregion, landscape and species or habitat type specific	2
No response	4

- 37 respondents indicated that they were involved in more than one means of providing information on biodiversity programs.
- 23 respondents were involved in habitat restoration projects, population management or stocking programs.
- restoration of wetlands (23 responses), nearshore lakes (15 responses) and offshore lakes (14 responses) were the top three habitat types involved in restoration or protection.
- 23 respondents use native species of flora and fauna for habitat restoration, population management and stocking programs, whereas 8 respondents use non-native sources, 12 use local sources, 3 use out of province/state sources, and 8 respondents use historical listings of pre-existing flora and fauna. Five respondents use all five options for projects.
- 20 respondents have implemented monitoring programs for habitat restoration projects.
- 7 respondents are involved in the propagation of native sources of plants or seed.
- 15 respondents maintain a database of sightings of rare, threatened or endangered species.
- 18 respondents contribute information to larger databases such as Canada's Natural Heritage Information Centre or the U.S. National Wetlands Inventory.
- 30 respondents indicated that they were aware of the United Nations Convention on Biological Diversity (UNEP 1992).
- 32 respondents indicated that they were aware of Canada's National Biodiversity Strategy and/or National Biological Survey in the U.S. and 13 respondents are involved in implementing part of these Biodiversity strategies.
- 20 respondents apply for funding from agencies that outline specific biodiversity goals or requirements as part of their approval.
- 18 respondents indicated that these funding agency requirements influence project design regarding biodiversity.
- 15 respondents indicated that they work in partnership with other organizations with differing goals regarding biodiversity.
- 22 respondents indicated that they use at least one of the technologies such as GIS, GPS, satellite imagery, maintenance of an electronic database to gain a better understanding of biodiversity.

The survey expanded upon the findings from the scoping exercise which revealed the vastness of the topic of biodiversity and habitat. A broad spectrum of organizations including universities, museums, government agencies, and grassroots environmental nongovernment organizations are involved in various aspects of biodiversity and habitat issues in the Great Lakes-St. Lawrence area and a majority (62%) have biodiversity goals, policy

objectives or mandates. There is also a variety in the efforts undertaken to assess biodiversity including cataloguing, database maintenance, research and volunteer-run species. All of these efforts contribute to the current knowledge and understanding of biodiversity and habitat in the Great Lakes-St. Lawrence area.

The Council identified a number of preliminary recommendations from the survey results which will help to increase the knowledge, understanding, and preservation of biodiversity and habitat since the protection of critical habitats is of utmost importance to preserving biodiversity.

- Develop ecosystem or ecoregional management approaches that protect and enhance critical habitats large enough to sustain viable, genetically diverse populations.
- Develop legislation and policies effective in stopping or slowing the introduction of non-native species.
- An oversight committee or organization both within the U.S. and Canada and between countries should be developed to provide a coordinated body for assimilation of the extensive amount of research, databases, atlases, cataloguing, etc. on biodiversity.
- Develop an approach to coordinate university research regarding biodiversity.
- Encourage an ecosystem or ecoregion approach to biodiversity and habitat restoration projects.
- Promote efforts to document information on small organisms such as non-vascular plants, microbes, algae, insects, and crustaceans. In aquatic systems these data are especially needed for near shore habitats.
- Encourage the coordination of US and Canadian biodiversity initiatives such as cataloguing by museums.
- Encourage the use of native species of flora and fauna when performing habitat restoration or enhancement projects.
- Encourage economically viable projects which promote the use and production of native species of flora and fauna.
- Coordinate programs with similar mandates such as fisheries or wetlands.
- Develop electronic means to share information and coordinate databases, cataloguing and research.
- Encourage the rehabilitation and enhancement of habitats such as golf courses, graveyards, corporate property, urban backyards, schoolyards, etc. to increase biodiversity.

From these preliminary findings and preliminary recommendations the Council developed two recommendations to the IJC.

The Council recommends that:

- **There is a critical need to develop ecosystem or ecoregional management approaches that protect and enhance critical habitats.**

- **There is a need for U.S. and Canadian coordination for assimilation of biodiversity and habitat research, databases, atlases, cataloguing and other ongoing programs.**

An oversight committee or organization both within the U.S. and Canada and between countries should be developed to provide a coordinated body for assimilation of the extensive amount of research, databases, atlases, cataloguing, etc. on biodiversity.

5.3 SCOPING ACTIVITIES

At its 27th meeting in Niagara Falls, Ontario, the Council defined an activity called "scoping" which was conducted at each of the Council's subsequent meetings. Below is the text of a resolution passed unanimously at that meeting:

> *The CGLRM will identify and prioritize the science needs and research activities needed to address IJC Biennial Priorities.*
>
> *The Council will use the Research Inventory and other sources of information to determine the current level of scientific knowledge on each priority and identify gaps in our knowledge and rank research needs to fill the gaps (scoping).*
>
> *The Council will report this information and any new priorities identified during the process to the Commission for transmittal to the Parties.*

The six topics in this section (as well as Biodiversity and Habitat in Section 2, above) were "scoped" by the Council during the 1997-1999 Priority Cycle. A summary of the results of each effort is included below.

5.3.1 Sediment Priority

There is a consensus among diverse sectors in the Great Lakes Basin (e.g., government, industry, non-governmental organizations, RAP groups) that contaminated sediment is an important element leading to many of the impairments to beneficial uses of the Great Lakes. All 42 Great Lakes Areas of Concern have contaminated sediment based on application of chemical guidelines. This universal obstacle to environmental recovery in Areas of Concern can potentially pose a challenge to restoring 11 of the 14 beneficial use impairments identified in the GLWQA (SedPAC 1997).

For RAPs, sediment management decisions need to be made bearing in mind the relationship between contaminated sediment and restoration of beneficial uses. This goes far beyond setting a numerical chemical cleanup criteria, as these are not based on the need to fully restore beneficial uses. The ultimate success of sediment management activities will be judged upon restoration of beneficial uses (e.g., elimination of fish consumption advisories, restoration of fish and wildlife populations, restoration of benthos).

Bioassessment frameworks have evolved substantially recently, and in many cases, large data sets have the required elements for developing a sediment management strategy. Equally important to the collection of data, however, is that sufficient attention be placed on thorough and comprehensive interpretation of the data. By employing scientifically sound methods of data interpretation, the information from an intensive sediment assessment can finally be integrated to make a decision to intervene (i.e., remediate contaminated sediment) or pursue source control and natural recovery as the preferred remedial option.

Research into ecologically meaningful data interpretation tools would advance sediment management decision-making by RAP practitioners. In addition to researching data interpretation tools, the Sediment Priority Action Committee (SedPAC) recognizes that the IJC can offer more assistance in the efforts to overcome obstacles to sediment management.

The Council supports SedPAC's findings that there are currently few, if any, simple or proven methods to predict recovery of use impairments based on sediment cleanup. More research is needed to quantify the relationships between contaminated sediment and known use impairments. The concept of ecological benefit forecasting (i.e., predicting ecological benefits and restoration of beneficial uses) is an important management need which, if accomplished, would be a substantial step forward.

Finally, deciding when to intervene is embedded with multiple elements. Data interpretation tools and techniques are a central element in developing the sediment management strategy. Other aspects involve what is and is not known about linking sediment clean up to ecological recovery and restoration of beneficial uses, as well as economic benefits that may accrue from effective management of contaminated sediment.

Existing studies that assess the economic benefits of remediating contaminated aquatic sediment are few. Most of the quantitative work to date has focused on the economics of navigational dredging and disposal. Further, given the lack of biophysical documentation that links sediment cleanup with beneficial use restoration, it is difficult to generate economic benefit estimates with any degree of rigor. Case studies using a range of economic valuation methods, applied to sites where sediment cleanup is complete, underway or proposed, is needed. These case studies will help identify the nature and extent of potential benefit types, and which valuation methodologies are best suited for the local characteristics of the remediation site. Perhaps most importantly, economic valuation can help legitimize the need to expedite sediment management decision-making in the Great Lakes basin.

5.2
5.3

The Council concurs with SedPAC in the following recommendations regarding contaminated sediment:

- **The Commission recommends to the Parties and Jurisdictions that they develop and reach agreement on methods or programs to predict and measure successful ecological recovery in Areas of Concern (e.g., ecological benefit forecasting, monitoring and surveillance programs to measure use restoration); and**

- **The Commission recommends to the Parties and Jurisdictions that they establish procedures for consistent data collection and interpretation across Areas of Concern, recognizing the importance of site specificity in applying methodologies and tools.**

5.3.2 Indicators Priority Implementation

The emphasis for the Indicators Priority is on demonstrating feasibility of implementing indicators for the nine desired outcomes that were previously identified. The Indicators Implementation Task Force (IITF) has been sharing their metadata findings with SOLEC, and the two initatives are collaborating towards reporting on indicators. IITF has been examining indicators and measurements to track 9 desired outcomes of the water quality agreement (such as swimmability, fish edibility, drinkability). SOLEC has been considering ecosystem type indicators in regions or on a basin-wide perspective. Relationships between IITF indicators and those of SOLEC are now being catalogued.

Ecosystem objectives (equivalent to desired outcomes) are also being developed by LaMP (Lakewide Management Plans) and SOLEC is interacting with LaMPs. Currently, there is a list of several indicators under each of the nine outcomes. The IITF is also interested in the question of how to integrate data from different regions.

The Council formed a subcommittee to "scope" the indicator priority. Here are the results of the effort:

Current Status: There has been more than 25 years of work under the GLWQA. There has been more than 10 years of debate and discussion on indicators.

Gaps/Problems:

- no scientific/management consensus on some of the desired outcomes
- weak or inappropriate indicators for some desired outcomes
- local collection/storage/reporting of data, i.e. municipal or county level
- non-uniformity of data standards, methods, and coherence in spatial or temporal coverage

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. . . it is not at all clear that there is a quantitative relationship between increasing phosphorus loading and increasing fish production. It is quite possible that an increase in phosphorus load will only increase zebra mussel biomass. It was primarily this uncertainty that led to the deliberations of the phosphorus expert panel.

The Council identified the following research/data needs:

- Critical Path Analysis for implementation ie, by the year 2000, how can some indicators actually be happening (costed-out, data acquisition questions answered, management responsibility assigned).
- Global literature review and evaluation of indicator theory.
- Research and development of ecosystem models to illustrate theory and the quantitative relationship of indicators.
- Research to identify specific species, chemicals and space/time coverage for indicators.
- Great Lakes centralized meta-data base (ie. Data on data: who, where, QA/QC, etc.
- Research and development on tools for use of indicator data such as GIS (geographic information systems) and relational databases. These should be made available to local users.
- Coordinated, binational monitoring program driven by indicators.

5.3.3 Lake Erie

The Council first called for a Reference on Lake Erie at the April 1993 meeting in Atlanta. The request was based on the huge changes that were occurring in the ecosystem as the zebra mussel population expanded. This continues to be a priority area for the Council. In 1998 and 1999, the Council focused on:

- modeling efforts (previously discussed in the Modeling section);
- organizing two special meetings of regional experts to discuss phosphorus levels and loading; and
- supporting a major conference at the University of Windsor hosted by the Great Lakes Institute for Environmental Research and the University of Windsor, the Ohio Sea Grant College Program and Stone Laboratory at The Ohio State University, US EPA-Duluth, and National Water Research Institute of Canada.

Lake Erie Phosphorus Issue. In February 1998, the Lake Erie Committee of the Great Lakes Fishery Commission expressed grave concern over the drastic reduction in some important Lake Erie fish populations and requested that no further phosphorus loading reductions be made until managers had a better understanding of the impact. They also urged scientists on both sides of the border to focus research on this important issue. The Council rapidly brought together a group of about 50 experts on phosphorus, zebra mussels, and the Lake Erie ecosystem to discuss the issues, share their most recent research results, and make recommendations regarding research needs.

Kent State University hosted the first meeting of the group on April 23-24, 1998. The University of Buffalo hosted the second meeting on June 29-30, 1998.

The models developed in the 1970's to control phosphorus loading to Lake Erie in an effort to reduce algal production and decomposition rates (oxygen depletion rates in the hypolimnion of the central basin-eutrophication) recommended a loading target level of 11,000 metric tons/year. In the period from 1982 to 1993 - most recent period of good phosphorus loading data - the total phosphorus loading to Lake Erie has hovered around the target load, with annual loading varying from about 7500 metric

tons/year to about 12,500 metric tons/year depending on hydrology-driven non-point sources. This range of phosphorus loading reduced chlorophyll *a* concentrations to target levels; however, with the invasion zebra mussels in 1988 further reductions in phytoplankton standing crop were observed. It was this further reduction in phytoplankton coupled with the decreases in walleye standing crops that led to the questioning of the appropriateness of the 11,000 metric tons/year target phosphorous loading. However, it is not at all clear that there is a quantitative relationship between increasing phosphorus loading and increasing fish production. It is quite possible that an increase in phosphorus load will only increase zebra mussel biomass. It was primarily this uncertainty that led to the deliberations of the phosphorus expert panel.

This issue was discussed at great length at both the Kent State University and University of Buffalo meetings by the panel of experts. The Council's conclusions and recommendations follow.

Conclusions

1) Lake Erie is probably still very productive in the western basin, but primary productivity in the eastern basin is more problematic. More importantly, productivity goes down as one moves from west to east within the Lake.
2) The smelt fishery in the eastern basin has all but collapsed.
3) The zebra mussel has changed the ecosystem and food webs to the extent that it is entirely unclear that adding phosphorus will produce the kind of plankton populations needed to support larger fish populations of target species.
4) Recent blooms of blue-green algae (including the toxin producer *Microcystis)* can cause taste and odor problems and are clearly associated with the selective filtering/feeding of zebra mussels and their alteration of phosphorus cycling in the western basin.
5) Dissolved reactive phosphorus levels near zebra mussel beds are high.
6) Adding phosphorus is more likely to cause increases in blue-green algae populations and taste and odor problems with public drinking water supplies than increased fish populations.
7) Hypothetically, we considered several scenarios for increasing phosphorus loadings. It was determined that it would be unreasonable to expect that relaxing point source controls could be expected to increase annual loading by more than 10-20%; given that the natural variability in loading over the last 10-15 years has been close to 50%, it is unlikely that relaxing point source controls will greatly affect productivity in the lake.
8) The suggestion to increase phosphorus loading during the spring at a time when diatoms would be produced was not practical, because at that time phytoplankton populations did not appear to be phosphorus limited.

Recommendations

1) In view of the significant changes in the Lake Erie ecosystem that have occurred subsequent to the zebra mussel invasion, the group recommended that a new effort to quantify the relationship between phosphorus loading and lake productivity at all trophic levels was sorely needed.
2) Research to better understand lower trophic levels and the relationships between nutrients, phytoplankton and zooplankton, and zebra mussels is greatly needed.
3) Research to determine the relationship between nutrient loading and fish production is badly needed.
4) The research recommended in items 2-3, should be driven by and integrated by sophisticated ecosystem models. Only then can we achieve the quantitative relationship between phosphorus loading and walleye production that is necessary to address the question at hand.
5) All management agencies should be encouraged to maintain and reinvigorate their monitoring programs, including a statistically-significant yet cost-effective monitoring of phosphorus loading to the lake. It was observed that budget cuts have forced cutbacks in some monitoring programs to the point that it is no longer possible for the IJC to accurately estimate nutrient loading to Lake Erie.
6) At the Buffalo meeting, the group supported a plan to participate in the Lake Erie at the Millennium Program to better coordinate Lake Erie research and monitoring efforts.

Lake Erie at the Millenium Conference. The Council helped to support a major conference at the University of Windsor on April 26-28, 1999. This conference was hosted by the Great Lakes Institute for Environmental Research and the University of Windsor, the Ohio Sea Grant College Program and Stone Laboratory at The Ohio State University, US EPA-Duluth, and National Water Research Institute of Canada. The conference was attended by approximately 140 scientists and included sessions on:

- Physical Structure of Lake Erie;
- Lake Erie Loadings and Flux;
- Environmental Features;
- Open-Water Biotic Processes;
- Nearshore/Coastal Biotic Processes;
- Invaders; and
- Human-Related Concerns.

Each speaker summarized current knowledge on the topic, followed by a listing of research needs. A conference proceedings is being prepared by the University of Windsor. A series of 4-6 follow-up workshops on priority issues is planned. The first workshop, scheduled to occur during the fall of 1999, will focus on nutrients and the base of the food chain.

5.3.4 Great Lakes Commercial Aquaculture

Background: Great Lakes commercial aquaculture has been identified as an emerging issue. The wild harvest of fisheries has put tremendous pressure on natural populations worldwide, and in many instances has exhausted traditional fishing grounds and eliminated many species from the commercial catch. "By-catch", the incidental harvesting of unwanted species, is also a major concern. The United Nations estimates that nearly one-quarter of the protein in human diets derives from seafood. The underdeveloped world currently relies on seafood for nearly 50% of its protein requirements. The demand for seafood is predicted to continue to increase as the human population increases from roughly 5.8 billion today to an estimated 8 billion within the next 25 years. In order to meet this demand it is estimated that aquaculture will supply more than one half of the world's seafood by the year 2025. In the United States the seafood industry has an estimated annual sales of $40 billion (US). 1998 consumption of seafood in the U.S. was approximately 16 lbs. per capita.

Aquaculture activities are growing rapidly. This is in part due to an increase in the demand for seafood as a "healthy" red meat substitute. The aquaculture industry grew 265% in United States from 1980-1995 and is projected to produce 1.26-2.2 billion lbs. annually in the United States by the year 2000. In 1995, the Canadian aquaculture industry was valued at $289 million (Cdn.). In Ontario, the industry generated $50 million in 1995 (~7 million lbs.), principally through the farming of rainbow trout. Ontario forecasters are predicting a tripling of production by the year 2000. However, it is difficult to obtain accurate statistics on the industry in all states and provinces because no uniform accounting practices and regulations are in place. The majority of aquaculture operations are small (~$5000 per year), but the demand for larger facilities is growing rapidly. The industry provides opportunities for alternate aquatic businesses in some depressed regions and amongst some aboriginal communities associated with declining Great Lakes fisheries. Currently, very little infrastructure exists for this industry.

There are two basic types of aquaculture: within-lake and land-based facilities. Within-lake facilities consist of pen or cage cultures and at present this practice is at a low level within the Great Lakes and, for the most part, is restricted to Canadian waters. These are generally open-mesh nylon bags suspended from frames. Cage culture sites are concentrated principally Lake Huron/Georgian Bay and Lake Ontario (Bay of Quinte) farming rainbow trout. There are approximately 10 cage culture sites in the Great Lakes-St. Lawrence with 6-12 cages per site yielding approximately 22 tonnes of fish per cage annually.

Within the U.S. there appear to no active cage culture operations within the Great Lakes basin, and there appears to be little enthusiasm for cage culture operations in U.S. waters from either the natural resource management community or commercial operators.

Land-based aquaculture facilities include recirculating aquaculture systems (RAS), pond aquaculture, raceways, aquaria, garden ponds, and bait fish culture. Many of the potential problems resulting from the flow-through aquaculture systems typically used in a large portion of the industry today would be largely eliminated by recirculating aquaculture technology wherein the water is recycled and reused. Consequently, RAS are seen as a much more "environmentally friendly" technology, and an increasing number of land-based operations are secure, indoor facilities that utilize recirculating systems. Current recirculating systems, however, are expensive and the technology is in its infancy in terms of development. An R&D effort to establish cost effective RAS technologies is needed.

ISSUES: A number of technological, economic, environmental, regulatory, and health issues have arisen along with the rise in the aquaculture industry.

A major issue for the aquaculture industry is the regulations and guidelines that govern all phases of operations and best management practices including construction and termination. In many instances, the regulations in use are not designed with the aquaculture industry in mind, or they are lacking entirely. Environmental and regulatory issues surrounding aquaculture will need to receive more attention as the industry expands. Issues include: pond construction guidelines; well digging and aquifer sustainability and protection; water consumption; effluent discharge, treatment and water quality impacts on surface waters and wetlands; waste management; predator control (largely birds); disease infection, control and prevention; accidental release of exotic and/or domesticated species into the wild gene pool or ecosystem; land use and natural habitat modification for pond or lagoon aquaculture; packaging, processing, transportation, and food safety; and economic, operational, or aesthetic conflicts with commercial fishing, cottagers, boaters, First Nations land claims, the shipping industry, etc.

Research, Policy and Planning Needs:

There is a need for uniform, thoughtful legislation that minimizes environmental impacts but does not over-regulate the industry. This must be based on sound scientific knowledge and research. Kathy Shwayder at Great Lakes Commission is developing draft legislative language that could be adapted in various jurisdictions to fit local needs and suggests a permit approach that takes into account the relative risk of the operation to environmental integrity.

There is also a need for more uniform, clearly defined Best Management Practices (BMP) in commercial aquaculture, including siting criteria and monitoring requirements. Anne Kapuscinski and Deborah Brister (UMN St. Paul) are developing a "Model Management Program for Private Aquaculture" for the Great Lakes Fishery Commission's Council of Lake Committees. This computer-based system is designed to be a user-friendly, interactive program that will address within-lake, land-based, and secured aquaculture systems. The system is a computer-based decision support tool with 2 tiers of decision making whereby a manager, farmer, or other user determines whether a target species appears on a "consideration list" and if so, the user assesses risks to genetic diversity and ecological integrity. If present, the user or manager considers risk management measures, or denies a permit for the operation.

From its initial scoping exercise, the Council identified a number of research needs for the practice, monitoring, and management of aquaculture within the Great Lakes basin:

- determination of the actual number and types of aquaculture facilities currently in existence;
- development of standardized monitoring protocols, including what is essential for management, what are the requirements of scale (temporal and spatial), what parameters (chemical and biological) are diagnostic of impacts on water quality, local biological communities, etc.;
- development of siting criteria;
- development of mass balance accounting protocols and models for assessing nutrient loading following examples from marine cage culture and recirculating systems;
- development of safe, effective certified and approved drugs, therapeutants, water treatment chemicals, and disease control agents for use in aquaculture;
- development of efficient feeds that are not derived from fish meal;
- development of cost-effective RAS (Recirculating Aquatic Systems) to minimize high water consumption and effluent discharge;
- refinement of net and pen culture technologies;
- assessment of the potential effects of drawdown on aquifers, streams, rivers; and the capacity of streams, rivers and aquifers to sustain aquaculture facilities;
- assessment of methods to minimize predation, particularly from birds, via predator friendly technologies;

- assessment of the potential impacts of thermal alteration of receiving waters by aquaculture effluent discharges;
- assessment of the potential impacts of modification of existing wetlands and littoral areas;
- development of requirements that importation of aquaculture species to the Great Lakes jurisdictions be subject to the same consultative process as government importations and require similar controls to those used for soil and agricultural plants;
- establishment of a "clean list" of species eligible for private possession; and
- development of education and outreach tools in support of personal and industry responsibility and the implementation of best management practices.

5.3.5 Review of Progress of Governments in the Control and Management of Persistent Toxic Substances and Endocrine Disruptors

Persistent Toxic Substances (PTSs)

A. Findings in Humans

There is no evidence over the past five years of dramatic shifts in levels or types of bioaccumulating contaminants in tissues of residents of the Great Lakes basin. However, the levels of such contaminants in the tissues of people eating large amounts of Great Lakes fish continue to be several fold higher than in people who do not eat such fish. *SOLEC 1996*

Exposure
- At-risk populations continue to be exposed to PTSs. Some highly exposed groups have body burden levels 3-4 times higher than the background level (e.g., data from Schantz and coworkers on DDE, Hg, and PCBs).
- Fish consumption remains the major pathway for exposure to PTS in fish eaters. Levels of some contaminants in Great Lakes fish exceed state and federal guidelines. Contaminated sediments are also of concern.
- Sport fish eaters consume 2 to 3 times more fish than is estimated for the general population - FDA estimate is 6.5 grams/person-day, for example, Schantz and coworkers report that high-fish eaters consume over 32 lbs/yr; Anderson and coworkers indicate that fish eaters on average consume 55 meals/yr with some consuming twice this amount; and Kearney and coworkers found Lake Ontario fish eaters in Canada consumed approximately 21 g/day).
- The biological significance of these increases is uncertain. Preliminary evidence in humans of neurobehavioural effects has been reported by Jacobson et.al. and very recently by Mergler.

Demographics
- 4.7 million people consumed Great Lakes sport fish in 1994 / Fish is an essential component of diets of minority populations and Native Americans.
- Men consume more fish than women; men and women eat Great Lakes fish during most of their reproductive years.

Health Effects
- Reproductive function (e.g., delay in time to pregnancy and shortened menstrual cycles) may be disrupted by exposure to PTSs.
- Neurobehavioral and developmental deficits occur in newborns and continue through school-age children from in utero exposure to PTSs.
- Other systemic effects, e.g., self-reported liver disease and diabetes may be associated with elevated serum levels of PCBs.

Other Conclusions
- Weight of evidence can be used in lieu of causality.
- Data are compelling: People are continuing to be exposed, and there are health consequences associated with these exposures.
- There is an immediate need to put science to service in implementing health intervention / health promotion strategies where necessary.
- Strategies should recognize the importance and benefits of fish consumption to particular populations. Risk and benefit analysis is essential for meaningful strategies.

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B. Environmental Trends

- Concentrations of some persistent toxic substances in the Great Lakes in air, water, and biota appear to have leveled off, or declined only slightly, in recent years. 100 % of the Great Lakes waters continue to be under fishing advisories. PCBs are most commonly the focus of advisories issued in the basin, followed by dioxins, chlordane and mercury.
- The 1993 TRI data (USEPA Toxics Release Inventory data released in 1995) showed that all of the Great Lakes Basin states and counties had shown a decrease in releases of targeted chemicals between 1988 and 1993.
- USEPA's 33/50 Program was a nationwide voluntary effort aimed at reducing the releases and transfers of 17 targeted chemicals (including PCBs, Hg, Pb, and other heavy metals and organics) tracked under TRI, with a goal of 50% reduction by the end of 1995. The Program was successful, exhibiting 55.6% decrease from 1988, which is equivalent to a reduction of over 664 million lbs. In three areas of the basin (SE Chicago, NW Indiana, and SE Michigan), an average reduction of 62% was achieved.
- Up to 1997, Canada has reported substantial decreases in alkyl-lead (85%), octachloro-styrene (18%), dioxins and furans (66%), and benzo(a)pyrene (20%) primarily as a result of the ARET Program in the Great Lakes Basin.

Focus on Mercury

- Fish consumption advisories for human health have been issued in 38 states and Ontario and Quebec due to mercury.
- There was an 82% decline in mercury use in the USA from 1980-1995 due to bans in paints and pesticides, phaseouts in batteries, and reductions in industrial uses.
- Mercury emissions were also curtailed under the US federal Clean Air Act amendments. Eight Great Lake states have implemented numerous programs to reduce mercury. In 1996, the US chlor-alkali sector voluntarily committed to reduce emissions and use of mercury by 50% during the next decade.
- Canada and the US included mercury in the Binational Toxics Strategy signed in 1997.

Focus on PCBs

- Although banned or tightly restricted, all 5 Great Lakes, as well as numerous inland lakes and rivers, have fish consumption advisories as a result of PCB contamination.
- In the US, 12 major utility companies have accelerated their voluntary phasedown of electric equipment which contain PCBs.
- USEPA and many states are working to remove sediments contaminated with PCBs from Great Lakes rivers and embayments.
- In Ontario, 46% of high level PCBs have been decommissioned in Ontario. 30% of high level PCB wastes and 20% of low level PCB wastes have been destroyed.
- Measurable levels of PCBs can be found in the tissues of all residents of the Great Lakes basin (majority of monitoring is in blood and breast milk).

Focus on Pesticides.

- In US Great Lakes basin counties, the overall use of pesticides has decreased by almost 10 million lbs. from 1994-1995. Annual pesticide usage now stands at 57 million lbs.
- There is increasing concern about possible endocrine disrupting properties associated with some pesticides.
- A USEPA Great Lakes Basin Pesticide Report was made available in 1998.
- In 1996, Canada and Ontario confirmed zero use and availability of five priority substances (aldrin/dieldrin, chlordane, DDT, toxaphene, and mirex).

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Endocrine Disruptors

Background: A major issue in toxicology today is potential endocrine disruption. The current view is that a number of environmental chemicals and/or natural products may mimic, block, or alter hormonal activity in offspring and thus pose a hazard to normal development. Canada and the US have both initiated action to address scientific and regulatory issues related to endocrine disruptors.

US Activities: As a result of growing concerns regarding the presence of endocrine disruptors in food, water, and the environment, and the 1996 passage of the Food Quality Protection Act (FQPA) and the amendments to the Safe Drinking Water Act, USEPA was required to develop a screening and testing program. Specifically, EPA was required to:

- develop a screening program and testing program by August, 1998;
- implement the program by August, 1999, and;
- report to Congress on the program's progress by August 2000.

To implement this plan, USEPA formed the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC) in 1996 and charged this committee with providing advice on how to design an appropriate screening and testing program. The EDSTAC was composed of scientists and representatives from USEPA, other federal agencies, state agencies, industry, water providers, worker protection and labor organizations, national environmental groups, environmental justice groups, public health groups, and research scientists. The committee was organized into work groups, and as of July 16, 1998, the draft document developed by the EDSTAC committee had been accepted by the full committee and delivered to USEPA on September 1.

Summary of recommendations:

1. The universe of chemicals (+ 87,000) considered for screening and testing should include:
- all chemicals currently listed on the TSCA inventory (-75,500).

- all active ingredients (approximately 900) and approximately 2,500 inert ingredients used to formulate over 20,000 pesticide products.
- approximately 8,000 chemicals regulated by the FDA, including 5,000 ingredients in cosmetics and 3,000 food additives.
- naturally occurring non-steroidal estrogens (NONEs) and other naturally occurring or environmentally degraded chemicals.
- nutritional supplements (currently not regulated therefore difficult to estimate the number).

2. The screening and testing program should be implemented in a phased manner. This means the chemicals which are determined to be a high priority should be screened and, if necessary, tested prior to those which are determined to be a lower priority.

The proposed 2-tier battery follows.

Tier 1 was designed to detect chemical substances or mixtures capable of interacting with estrogen, androgen, or thyroid hormone systems. The recommended battery includes three *in vitro* assays, three *in vivo* mammalian assays, and two *in vivo* nonmammalian assays (Table 4).

Table 3 **Proposed Tier 1 Assays**

In Vitro	Estrogen Receptor (ER) Binding/Transcriptional Activation Assay Androgen Receptor (AR) Binding/ Transcriptional Activation Assay Steroidogenesis Assay with Minced Testis
In Vivo	Rodent 3-day Uterotrophic Assay (Subcutaneous) Rodent 20-day Pubertal Female Assay with Thyroid Rodent 5-7-day Hershberger Assay Frog Metamorphosis Assay Fish Gonadal Recrudescence Assay
Alternate assays for possible inclusion:	
In Vitro	Placental Aromatase Assay
In Vivo	Modified Rodent 3-day Uterotrophic Assay (Intraperitoneal) Rodent 14-day Intact Adult Male Assay With Thyroid Rodent 20-day Thyroid/Pubertal Male Assay

Tier 2 was designed to characterize the nature, likelihood, and dose-response relationship of endocrine disruption of estrogen, androgen, and thyroid in humans and wildlife. These tests are longer term studies designed to encompass critical life stages and processes, a broad range of doses, and administration by a relevant route of exposure. A more comprehensive profile of biological consequences of chemical exposure can be identified and related to the dose of exposure which caused them. Tests will usually encompass 2 generations since effects associated with endocrine disruption may be latent and not manifested until later in life or may not appear until the reproductive period is reached (Table 5).

. . . it is strongly recommended that health risk research be coordinated so as to develop (the) linkage between source and effects through the exposure pathway.

Table 4 **Proposed Tier 2 Tests**

Mammalian Tests
• Two-generation Mammalian Reproductive Toxicity Study; or
• A Less Comprehensive Test (when appropriate): Alternative Mammalian Reproductive Test; or One-Generation Test
Multigeneration Tests in Other Taxa
• Avian Reproduction (with bobwhite quail and mallard)
• Fish Life Cycle (fathead minnow)
• Mysid Life Cycle (*Americamysis*)
• Amphibian Development and Reproduction (*Xenopus*)

Canadian Activities: Health Canada works with Environment Canada on an inter-departmental committee on endocrine disruptors. The committee coordinates research activities and provides support for policy initiatives required to address endocrine disrupting substances currently in the environment, found in food, consumer products or drugs, or as pesticides, or those that may enter into commerce in the future.

Health Canada has an endocrine disruptor committee that addresses research, regulatory, and policy issues.

Health Canada also participates in international activities under the OECD Working Group on Endocrine Disruptor Testing and Assessment and the WHO/IPCS Steering Committee for the Global Assessment of Endocrine Disruptors.

An increase in research funding will be directed to endocrine disruptors and their implications for health and the environment in 1999.

In assessing the risk of a persistent toxic substance or possible endocrine disruptor in the Great Lakes, it is necessary to consider both exposure potential and effects potential. Ideally, we have a good quantitative understanding of the entire pathway from source to transport and fate to bioaccumulation to effects (either human or ecological). Therefore, it is strongly recommended that health risk research be coordinated so as to develop this linkage between source and effects through the exposure pathway. Agencies responsible for environmental fate and exposure research should continue to closely coordinate with those responsible for health effects research. Indeed, the development of programs of coordinated, synoptic studies of specific contaminants of concern in specific ecosystems is the best way to develop this linkage.

The Council recommends that:

- **There is an immediate need to put science to service in implementing health intervention / health promotion strategies where necessary.**

- **All strategies should recognize the importance and benefits of fish consumption to particular populations.**

5.3.6 RAP and LaMP Research Needs

Purpose: A primary function of the Council of Great Lakes Research Managers is to advise the International Joint Commission on research needs related to the implementation of the Great Lakes Water Quality Agreement. The purpose of this white paper is to help determine the research needs associated with development and implementation of Remedial Action Plans (RAPs) under Annex 2 of the Agreement, and to begin a process of building a common understanding of the priorities.

Articulation of RAP Needs

In recent years, there have been three separate attempts to articulate the needs of RAPs, both in general terms and specifically related to research. As part of a Workshop on Research, Assessment, and Analysis at the 1996 SOLEC, a breakout session was conducted with the principal theme of "Improving the Effectiveness of Great Lakes Research." Breakout groups were instructed to participate in subgroups that addressed questions relating to the overall Great Lakes research arena. One of the subgroups consisting of about 10 individuals addressed the area of RAPs and LaMPs. While this is a small subgroup of respondents and therefore does not constitute basin-wide consensus, some insightful findings were revealed.

From the discussions, two general types of RAP/LaMP research needs emerged:

1) Research to support the development of technologies for remediation, mitigation or restoration. Particular research requirements would depend dependent on the specific types of degradation, such as sediment and habitat.

2) A second class of research needs surrounded benefits forcasting. This consists of methods and data that enable RAP practitioners to evaluate and predict future conditions in response to remediation scenarios. These types of analytical tools were identified by category of study (e.g. ecology, socio-economic).

The consideration of monitoring and surveillance within the context of research was also highlighted.

The articulation of RAP needs has also been conducted by the IJC Sediment Priority Action Committee (SedPAC), who prepared a white paper on the "Overcoming Obstacles to Sediment Remediation in the Great Lakes Basin" (IJC, 1997). Contaminated sediment is a major factor limiting the implementation of many RAPs and the ability to restore beneficial uses. The paper identified the following six obstacles to sediment remediation in Great lakes Areas of Concern:

- limited funding and resources;
- regulatory complexity;
- lack of a decision-making framework;
- limited corporate involvement;
- insufficient research and technology development; and
- limited public support.

To overcome these obstacles, research needs surround the creation of innovative funding formulas, policy and legislative flexibility, science-based data interpretation tools, private sector incentives, technology, and public awareness, consultation and engagement.

The most recent articulation of RAP needs was presented by the IJC in a paper entitled "Beacons of Light: Special Report on Successful Strategies Toward Restoration in Areas of Concern under the Great Lakes Water Quality Agreement" (IJC 1998). This paper identified the following seven major obstacles to implementation of RAPs:

- lack of planning for implementation of "big ticket" remedial measures;
- reductions in government support with no associated increase in local capacity;
- failure to set priorities within and between AOCs;
- public participation;
- information transfer; and
- failure to quantify benefits of remediation, particularly regarding human health.

Analysis of RAP Needs

Using the above, recent efforts to articulate the needs of RAPs, one possible way of analyzing these needs is by grouping them according to their root cause. The causes of these needs might be considered as three major categories of limitations:

- process limitations;
- funding/resource limitations; and
- science/research limitations.

These categories are artificial, and not exclusive, but may enable us to discriminate science/research-limited needs from those limited by other factors. While some needs may be due to a single limitation, most are probably limited by two or all three to a degree. In an effort to examine the RAP needs systematically, the RAP needs have been matched with limitations on the attached matrix (Table 3).

This cursory analysis suggests that the majority of RAP needs are either process or funding limited. While science/research appears to be the primary limitation for only a few RAP needs, it is a contributing limitation for more than half.

Table 5 **Analysis of Great Lakes RAP Needs**

RAP Need	Limitations		
	Process	Funds	Science
Remediation technologies		++	+
Evaluation & predictive tools		+	+
Regulatory/policy changes	++		+
Monitoring data & information		++	+
Decision-making framework	+		+
Corporate involvement	+	++	
Public support	++	+	+
Planning for hi-cost features	++		
Information transfer	++		
Benefit quantification		+	++

Legend: primary limitation ++
contributing limitation +

5.4 RESEARCH SUPPORT ACTIVITIES

5.4.1 Research Vessel Coordination

The Second Annual Great Lakes Research Vessel Coordination Workshop was held in Ann Arbor on March 3-4, 1998. The workshop focused on several of the 37 recommendations made concerning research vessels at the first workshop. Three important areas were:

1. **Communication and Information Sharing**
   Information about the research vessels and their schedule are made available to managers and operators via the Internet. This has been received very enthusiastically by boat captains and has already saved money.

2. **Institutional Information Requirement**
   There is a real need to establish lake committees so that coordination can occur in smaller, workable units. This would also encourage memorandums of understanding and interagency agreements to allow efficient partnering. It was also suggested that an IJC committee could focus on research vessel coordination.

3. **Program Development and Coordination**
   The 1998 Science Vessel Inventory provides the State of the Fleet. There are 62 vessels over 30 feet in length counting U.S. and Canadian boats including the Coast Guard. The average age of the boats is 30 years and the average length is 50 feet.

Based on this inventory, the conclusion was that the fleet is not adequate to meet Great Lakes science needs. The Great Lakes fleet should be compared to the coastal marine fleet on the east coast, for example, where the equipment is much newer and larger, even though the Great Lakes area is a tougher environment to work in and has a much longer coastline. In fact, there is only one vessel, the U.S. EPA's Lake Guardian that is capable of year round work on the lakes in most conditions. Because of this, data gaps occur during periods when most boats cannot work, i.e. November through March. This message should get out to a broader audience. Funding for further coordination is needed and support for a Great Lakes Protection Fund proposal is required. For example, an effort should be made to organize the web pages that different vessels may already have. One possibility is that a boat's schedule may be available to others so that ship time can be efficiently used.

The Third Annual Workshop on Great Lakes Science Vessel Coordination was held in Windsor on February 17-18, 1999. This year, the keynote address was given by the Canadian Cochair of the Council, Harvey Shear. The University-National Oceanographic Laboratory System (UNOLS) system (http://www.gso.uri.edu/unols/unols.html) for marine research laboratories was described at the workshop. There are three full-time equivalent staff devoted to schedule coordination. Only the University of Michigan boat, the Laurentian, is part of this system. The Council recommends that a UNOLS type system should be used to coordinate Great Lakes Research Vessels. The potential benefits of coordination on the basin level are enormous.

The Council recommends that:

- **A system like the University-National Oceanographic Laboratory System (UNOLS) should be used to help coordinate and maximize/optimize use of Great Lakes Research Vessels.**

5.4.2 Joint Initiatives with IAGLR

1. New Research Priorities. Session Chairs at the Annual IAGLR Conference have been asked to help identify research needs that come out of their sessions. The following motion was passed unanimously at the Council's 30th Meeting in Montreal:

   "The Council will donate annually to IAGLR $1,000.00 which will be used to conduct a survey of emerging research needs which will be compiled and summarized and published as a Commentary and Editorial in the Journal of Great Lakes Research (JGLR).

2. Agency Presentations on Research Needs. Another motion that was passed is for heads of major research laboratories to present their current research needs at the Annual IAGLR Conference each year. This should be of interest to government funders and organizations including some groups which cannot fund directly but can partner, such as U.S. Geological Survey. The following motion was made and passed unanimously:

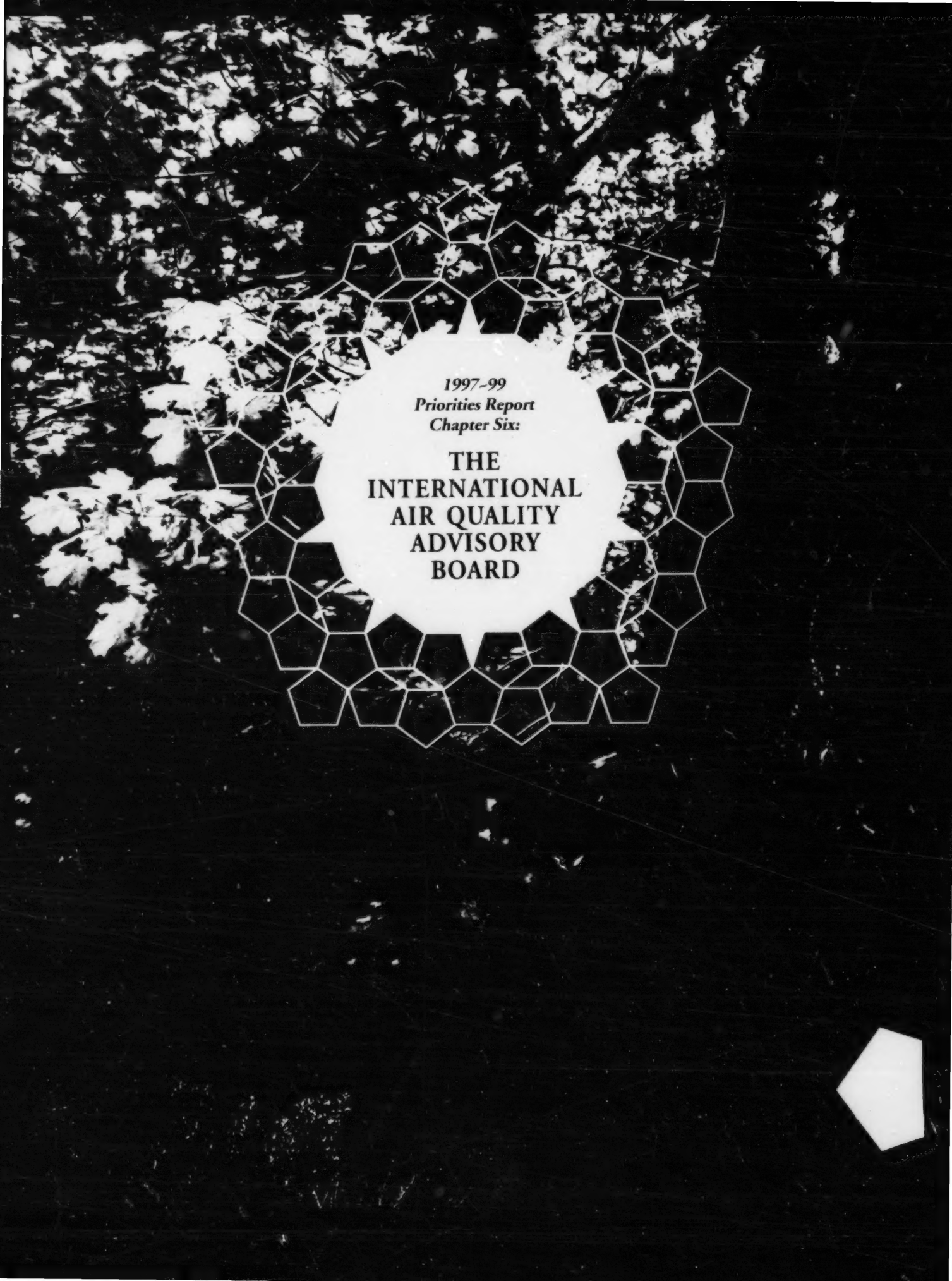
   "Hold a session annually at IAGLR where funding agencies would present their funding or collaboration possibilities to the audience."

5.5 CONCLUSIONS

Scoping of the Aquaculture Priority revealed many questions and research needs. However, it is clear that the actual number and types of aquaculture facilities currently in existence needs to be determined and that there is an urgent need for uniform, thoughtful legislation, operational guidelines and best management practices that minimize environmental impacts but do not over-regulate the industry. There is also a need for research and development of environmentally-friendly recirculating system technologies that can grow food with minimal impacts on natural waters and environmental quality.

The Modeling Summit continues to be an effective way to bring together modelers and resource managers to discuss how ecosystem modeling can aid in accomplishing the goals of RAPs, LaMPs and indicator selection and development. The Council is pleased to convene the summit at various venues including SOLEC and IAGLR and notes that its objective of identifying research needs, gaps and priorities is furthered by the regular scheduling of these events. Future summits may continue to be held on a lake specific basis or be organized around other themes such as a session in which modelers and managers collaborate to implement a solution to some pressing management problem.

Biodiversity in the Great Lakes basin is affected by the activities of a tremendous number of organizations and programs. However, there is no single agency or group that has the responsibility and authority to protect biodiversity. There is a critical need to develop ecosystem or ecoregional management approaches that protect and enhance critical habitats large enough to sustain viable, genetically diverse populations. Further, an oversight committee or organization both within the U.S. and Canada and between countries should be developed to provide a coordinated body for assimilation of the extensive amount of research, databases, atlases, cataloguing and other ongoing programs on biodiversity.



1997–99
Priorities Report
Chapter Six:

THE INTERNATIONAL AIR QUALITY ADVISORY BOARD

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6.1 INTRODUCTION

LINKING CANADA AND UNITED STATES SOURCES AND SOURCE REGIONS OF SELECTED PERSISTENT TOXIC SUBSTANCES TO DEPOSITION IN THE GREAT LAKES BASIN: A PROGRESS REPORT

In 1985, the Great Lakes Water Quality Board of the International Joint Commission (IJC) designated eleven critical pollutants in the Great Lakes basin. It did so in the knowledge that there were several significant pathways for these contaminants to reach the lakes, including atmospheric transport and deposition. The governments of the United States and Canada created Annex 15 (Airborne Toxic Substances) of the Great Lakes Water Quality Agreement to provide for further research and control of this contaminant pathway.

Further, in 1997, the governments of the United States and Canada jointly developed the Great Lakes Binational Toxics Strategy (BTS) (Canada and United States, 1997) with commitments to quantified reductions in the amount of contaminants released into the environment. The complete listing of Level I and Level II persistent, bioaccumulative substances designated under the strategy is shown in Table 1. Level I contaminants are largely those designated as critical pollutants by the Water Quality Board in 1985.

Pollutants can enter a given lake through a variety of pathways, including atmospheric deposition, direct discharge or surface-runoff into the lake or its tributaries, and resuspension of contaminated sediments. Depending on the nature of the pollutant and the location and character of its sources, the relative contribution of each pathway will be different for each pollutant for a given lake. Unfortunately, for many pollutants of concern in the Great Lakes, there is insufficient information to make mass balance estimates. However, in a few instances, sufficient measurements have been made to make estimates of the relative importance of different loading pathways. While the estimates shown in Table 2 are very uncertain, it appears that the atmospheric deposition pathway is predominant for some pollutants for some lakes. For example, atmospheric deposition appears to be the dominant loading pathway for Lake Superior (for the pollutants for which estimates could be found, i.e., Table 2).

Table 1 **Persistent Toxic Substances (Level I and Level II) Identified in the Great Lakes Binational Toxics Strategy**

Critical pollutants identified by WQB in 1985 are indicated with an asterisk (*). Persistent organic pollutants from CEC Council Resolution #95-5 are identified with a caret (^).

LEVEL I	LEVEL II
Aldrin ^	Cadmium and its compounds
Dieldrin *^	1,4-Dichlorobenzene
Benzo(a)Pyrene {B(a)P} *	3,3'-Dichlorobenzidine
Chlordane ^	Dinitropyrene
DDT, DDD, DDE *^	Endrin^
Alkylated lead *	Heptachlor and heptachlor epoxide
Mercury * and its compounds	Hexachlorobutadiene (1,2- and 1,3-)
Mirex *^	Hexachlorocyclohexane (including alpha, beta, delta, lindane)
Octachlorostyrene	4,4'-Methylenebis (2-chloroaniline)
PCBs *^	Pentachlorobenzene
Dioxins (PCDD; 2,3,7,8-TCDD) *^	Pentachlorophenol
Furans (PCDF; 2,3,7,8-TCDF) *^	Tetrachlorobenzene (1,2,3,4- and 1,2,4,5-)
Toxaphene *^	Tributyl tin
	Polycyclic aromatic hydrocarbons (PAHs)^ as a group, including but not limited to:
	-Anthracene -Perylene
	-Benzo(a)anthracene
	-Phenanthrene
	-Benzo(g,h,i)perylene

NOTE: Hexabromobiphenyl and Pentachlorophenol are listed as POPs on the CEC Council Resolution #95-5 but are not included on the Strategy list.

Table 2 **Percent of Great Lakes Loadings Attributable to the Atmospheric Deposition Pathway[1]**

Pollutant	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
DDT	97[a]	98[a]	97[a]	22[a]	31[a]
Lead	97[a]; 64[b]; 69[d]	99[a]	98[a]	46[a]	73[a]
Mercury	73[d]	> 80[j]	[k]	[k]	[k]
PCB's	90[a]; ~ 95[b,c]; 82[d]	58[a]	78[a]	13[a]	7[a]
PCDD/F	~100[e]; ~80[f]	50-100[e] (PCDD); 5-35[e] (PCDF); 88[f]	86[f]	~40[f]	5-35 (PCDD)[e]; < 5 (PCDF)[e]
Benzo(a)pyrene	96[a]	86[a]	80[a]	79[a]	72[a]
Hexachlorobenzene	99[f]	95[f]	96[f]	> 17[f]	40[f]
Atrazine	97[h]	~30[g]; 23[h]	~20[h]	~10-20[h]	~5[h]
Mirex	[k]	[k]	[k]	[k]	~5[a]

References and Notes

1 there are significant uncertainties in most, if not all, of the estimates in this table.

(a) Strachan and Eisenreich (1988), percentages of total inputs; (b) Hoff *et al.* (1996); (c) Net loss of PCB's to the atmosphere of 1600 kg/year; total non-atmospheric inputs of approximately 70 kg/year; (d) Dolan *et al.* (1993); (e) Pearson *et al.* (1998); (f) Cohen *et al.* (1995); (g) Rygwekski et al. (1999); (h) Schottler and Eisenreich (1997); (j) Mason and Sullivan (1997); (k) no estimates could be found.

For persistent toxic substances for which atmospheric deposition may be a significant loading source to the lakes, it is critical to determine:

- the amount of such deposition to the lakes;
- the relative importance of contributions from local, regional, national, continental, and global source regions; and
- the relative importance of different source categories.

These elements are necessary to develop strategic and defensible programs and policies for reducing loadings and associated toxicological effects.

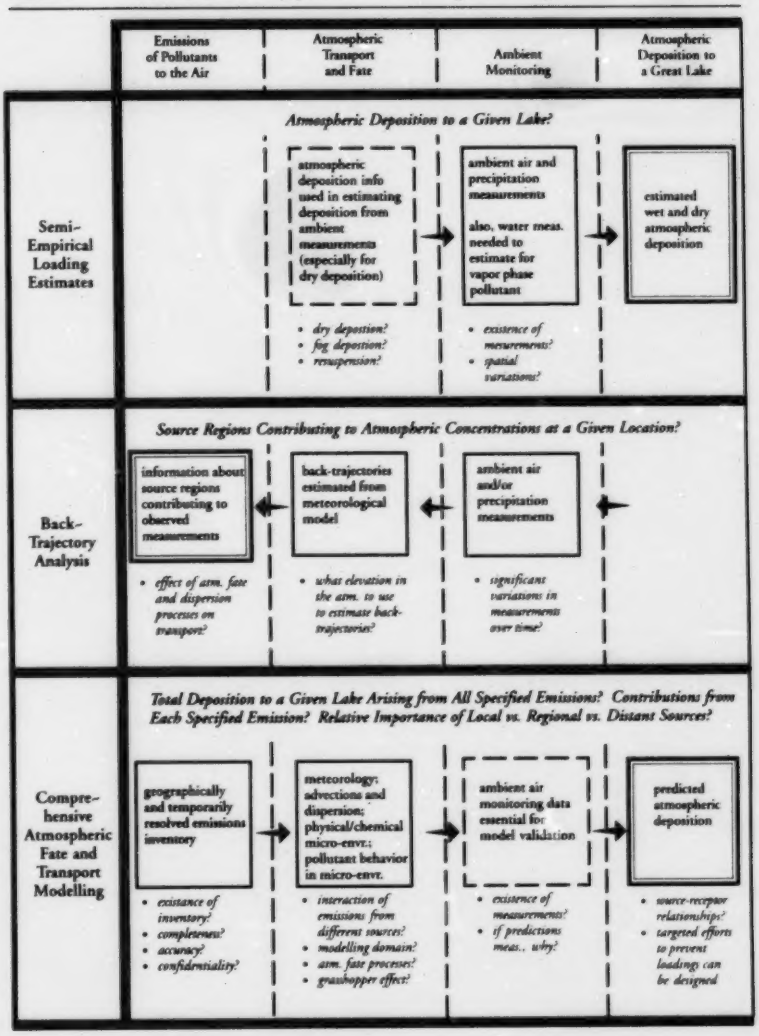
Unfortunately, for many pollutants of concern in the Great Lakes, there is insufficient information to make mass balance estimates. However, in a few instances, sufficient measurements have been made to make estimates of the relative importance of different loading pathways. While the estimates shown in Table 2 are very uncertain, it appears that the atmospheric deposition pathway is predominant for some pollutants for some lakes.

6.2 METHODOLOGICAL OPTIONS FOR ANALYSIS OF THE ATMOSPHERIC DEPOSITION PATHWAY

The mechanism and influences governing the atmospheric deposition pathway are complex. In contrast, for example, to the direct loading pathway - in which liquid effluent is discharged directly into the lake - air emissions are subject to advection, dispersion, transformation, deposition and possible re-emission processes between the source and the lake. The characteristics of weather patterns between the source and the lake influence this pathway significantly, and, different pollutants can exhibit quite different behavior in the atmosphere. In general, pollutant-specific atmospheric modeling is necessary to understand the linkages between sources and the lakes. As modeling is an inherently uncertain process, evaluation of the validity of the simulation results — generally by comparison against ambient monitoring data — is crucial.

There are several distinct methodological approaches available to develop information on the atmospheric deposition pathway. Three major approaches are summarized in Table 3: semi-empirical loading estimates, back-trajectory calculations, and comprehensive modeling.

Table 3 **Methods for Analysis of the Atmospheric Deposition Pathway**


Emissions of Pollutants to the Air
Atmospheric Transport and Fate
Ambient Monitoring
Atmospheric Deposition to a Great Lake
Semi-Empirical Loading Estimates
Atmospheric Deposition to a Given Lake?
atmospheric deposition info used in estimating deposition from ambient measurements (especially for dry deposition)
ambient air and precipitation measurements
also, water meas. needed to estimate for vapor phase pollutant
estimated wet and dry atmospheric deposition
• dry deposition?
• fog deposition?
• resuspension?
• existence of measurements?
• spatial variations?
Back-Trajectory Analysis
Source Regions Contributing to Atmospheric Concentrations at a Given Location?
information about source regions contributing to observed measurements
back-trajectories estimated from meteorological model
ambient air and/or precipitation measurements
• effect of atm. fate and dispersion processes on transport?
• what elevation in the atm. to use to estimate back-trajectories?
• significant variations in measurements over time?
Compre-hensive Atmospheric Fate and Transport Modelling
Total Deposition to a Given Lake Arising from All Specified Emissions? Contributions from Each Specified Emission? Relative Importance of Local vs. Regional vs. Distant Sources?
geographically and temporarily resolved emissions inventory
meteorology: advections and dispersion; physical/chemical micro-envt.; pollutant behavior in micro-envt.
ambient air monitoring data essential for model validation
predicted atmospheric deposition
• existance of inventory?
• completeness?
• accuracy?
• confidentiality?
• interaction of emissions from different sources?
• modelling domain?
• atm. fate processes?
• grasshopper effect?
• existence of measurements?
• if predictions meas., why?
• source-receptor relationships?
• targeted efforts to prevent loadings can be designed

In the *semi-empirical loading approach*, ambient measurements are used to estimate the deposition of a given pollutant to a given lake. Analyses of this type include those by Hoff *et al.* (1996) and Eisenreich and Strachan (1992). In this approach, the extent to which the available ambient measurements are also representative of the concentrations over the entire lake - information which is sometimes not known - will strongly influence the accuracy of the estimates. In addition, it is difficult to develop any information about source-receptor relationships using only this method. [1] That is, an estimate of the total deposition to a given lake can be made, but the sources of this deposition will remain unidentified.

In *receptor-oriented techniques*, information about sources is inferred from measurements at the receptor. In one common receptor-based methodology - the *back-trajectory approach* - the paths of air masses that arrive at a particular location are estimated based on a meteorological model. Generally, locations with ambient monitoring data are selected for analysis. A common technique is to investigate where the air masses, associated with high (or low) ambient measurements at the study site, originated. This yields information on source regions expected to be large (or small) contributors to the observed concentrations. If the study site is sufficiently representative of the concentrations of the specific Great Lake as a whole, then inferences can be made regarding the likely source regions of importance to the lake. In addition, when the back-trajectory analysis results are compared to emissions inventory information, inferences regarding the

1 In this chapter, the term "receptor" is used to signify a lake or lake basin.

likely source categories contributing significantly to the lake can sometimes be made. Examples of back-trajectory analyses applied to Binational Toxics Strategy (Canada and United States 1997) pollutants in the Great Lakes region include those by Hoff *et al.* (1992a, b), Gao *et al.* (1996), and Blanchard *et al.* (1997).[2] Biegalski *et al.* (1998) applied several alternative receptor-based methodologies (factor analysis, elemental ratios, and enrichment factor analysis) to investigate source-receptor relationships in the Great Lakes basin.

In the *comprehensive modeling approach*, an emissions inventory of the pollutant of interest is used as an input to an atmospheric fate and transport model. The model attempts to simulate the transport, dispersion, transformation, and deposition of the pollutant emitted from each source in the inventory. Examples of this approach for one or more BTS pollutants in the Great Lakes basin include the analyses of Voldner and Schroeder (1989), Clark (1992ab), Shannon and Voldner (1995), and Cohen *et al.* (1995, 1997b).

In the work described here, the comprehensive modeling approach has been taken, using a particular fate and transport model (HYSPLIT). In the following sections, the general methodology used will be briefly described. Following these general methodological considerations, preliminary results for dioxin will be presented.

A common technique is to investigate where the air masses, associated with high (or low) ambient measurements at the study site, originated. This yields information on source regions expected to be large (or small) contributors to the observed concentrations. If the study site is sufficiently representative of the concentrations of the specific Great Lake as a whole, then inferences can be made regarding the likely source regions of importance to the lake.

2 Interpretation of back-trajectory analytical results can be complicated by a number of factors. The distance between a known or hypothesized source location and the measurement site obviously influences the extent of its measured concentrations; dispersion, deposition, and chemical transformation *en route* will all generally serve to lower the atmospheric concentration of the pollutant with increasing distance from any given source. These processes are dependent on the physical-chemical properties of the particular pollutant and the many features of the atmospheric environment encountered by the polluted air parcel in between the source and the measurement site. These factors can make it difficult to determine the location - on a given back trajectory - of the significant source(s).

6.3 A PROJECT USING THE COMPREHENSIVE MODELING APPROACH

In this context, seeking to develop the tools necessary to take a strategic approach to the aforementioned binational agreements, over the past four years, the International Air Quality Advisory Board of the International Joint Commission, co-chaired by Dr. Gary Foley of the U.S. EPA and Dr. Don McKay of Environment Canada, have initiated a collaborative, multi-agency effort to comprehensively determine the sources responsible for atmospheric deposition to the Great Lakes through application of an atmospheric model. The contaminants under current investigation with this methodology include dioxin, atrazine, and cadmium. This report will examine, in some detail, the development of linkages between U.S. and Canadian sources of dioxin and individual lake basins in the Great Lakes region.

As the modeling analysis is not yet complete, the discussion that follows is in the form of a progress report. Preliminary results, where available, will be presented. As the dioxin analysis is furthest along at the present, the development of linkages between U.S. and Canadian sources of dioxin and individual basins in the Great Lakes will be discussed here. A more detailed discussion of this project is available as a free standing report.

6.3.1 Availability of Emissions Inventories

As the board noted in its chapter of the IJC 1995/97 Great Lakes Priority Report, emissions inventories are critical to the successful execution of any modeling effort. Geographically and temporally resolved emissions inventories are needed for any compound for which a comprehensive modeling analysis is to be performed. Thus, one of the first steps in this work was determining the availability and adequacy of emissions inventories for each of the compounds of concern in the Great Lakes. At the present time, for all of the Binational Toxics Strategy pollutants, relatively accurate binational inventories only appear to be available or potentially available for dioxin, cadmium, mercury, hexachlorobenzene (HCB), and possibly one or more polycyclic aromatic hydrocarbon (PAH) compounds. For these contaminants, the development, verification and subsequent mapping of a truly binational inventory is a required first step in the modeling process. In addition, a binational emissions inventory is available for atrazine, a widely used herbicide on corn and sorghum.

Given the need for a relatively comprehensive emission inventory, the compounds chosen for further consideration in this phase of the project include dioxin, atrazine, cadmium, and mercury.[3], [4], [5] Results for the first three of these compounds are anticipated by Fall 1999, and results for mercury should be available in the following year.

The inventories selected for use in this phase are summarized in Table 4. The International Air Quality Advisory Board has established a binational body, the Emissions Inventory Working

Table 4 **Summary of Inventories Currently Identified for Use in Project**

Inventory Developer	Pollutant	Spatial Extent	Spatial Resolution	Temporal Resolution	Notes
Center for the Biology of Natural Systems, Queens College NY	PCDD/F (dioxins)	United States	Major point sources and county-resolution area sources	Annual emissions for 1996	
Environment Canada	PCDD/F	Canada	Major point sources and both census division and gridded data for area sources (50 km grid around Great Lakes, 100 km grid in remainder of Canada).	Annual emissions for 1995	
U.S. EPA National Toxics Inventory	Cadmium	United States	County resolution for all source categories	Annual emissions, nominally for 1993	
Environment Canada	Cadmium	Canada	Major point sources and both census division and gridded data for area sources (50 km grid around Great Lakes, 100 km grid in remainder of Canada).	Annual emissions for 1995 and for 1990	Estimates of emissions for 1993 may be developed by Environment Canada
Center for the Biology of Natural Systems, Queens College NY	Atrazine	United States and Canada	County resolution for the U.S., and a 127x127 km emissions grid in Canada	Weekly emissions for March-July 1991	Based partly on emissions factors developed by Ortech Ltd.
U.S. EPA National Toxics Inventory	Mercury	United States	County resolution for all source categories	Annual emissions, nominally for 1994-5	
Environment Canada	Mercury	Canada	Point sources for major facilities and both census division and gridded data for area sources (50 km grid around Great Lakes, 100 km grid in remainder of Canada).	Annual emissions for 1995.	

Group, to provide expert overview and comment on the inventories considered for use and to support the development and mapping of binational inventories. Each of the inventories is subject to a preliminary evaluation for completeness and accuracy using a variety of approaches, including the following:

- an assessment of the degree to which each inventory contains all significant source categories[6] for a given pollutant;
- an assessment of the quality of the emissions data in individual source categories, based on current knowledge of emissions;
- an assessment of the degree of geographical coverage of each inventory; for example, if a source category is known to be relatively ubiquitous, and it is only present in the inventory in a small number of geographical regions, then the inventory cannot be considered complete; and
- a comparison for consistency, in cases where independent U.S. and Canadian inventories exist (e.g. cadmium, mercury and dioxin) [For example, if one inventory contains information for a given source category, but the other does not, then this point will be noted. Unfortunately, information necessary to carry out these types of detailed comparisons is not currently available for many of the utilized inventories. Nevertheless, some form of comparison will be attempted.].

Corrections or qualitative discussion of any limitations identified through the above process is being included in the analysis.

6.3.2 Atmospheric Fate and Transport Modeling

The NOAA HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory) computer model has been chosen to simulate the atmospheric fate and transport of pollutants from sources in the United States and Canada to the Great Lakes. HYSPLIT was originally developed at the U.S. National Oceanic and Atmospheric Administration (NOAA) for medium and long-range transport modeling of accidental releases of radioactive materials. It is currently used operationally for emergency response at NOAA. The development, validation, and operation of HYSPLIT are described elsewhere (Draxler *et al.*,1998, 1991ab; Draxler, 1987, 1992).

HYSPLIT is a Lagrangian model, in which puffs of pollutant are emitted from user-specified locations, and are then advected, dispersed, and subjected to destruction and deposition phenomena throughout the model domain. It has been used to simulate many different atmospheric processes, including sulfur transport and deposition in the U.S. (Rolph *et al.*,: 1992, 1993) and dispersion of pollutants from Persian Gulf oil fires (Draxler *et al.*,1994; McQueen *et al.*, 1994). HYSPLIT has been specially modified for the work discussed here, so that it can better simulate the fate of the pollutants being considered. Simplified schematics of its structure and operation are shown in Figures 1 and 2. Similar to most atmospheric fate and transport models, HYSPLIT uses gridded meteorological data computed by an external model.

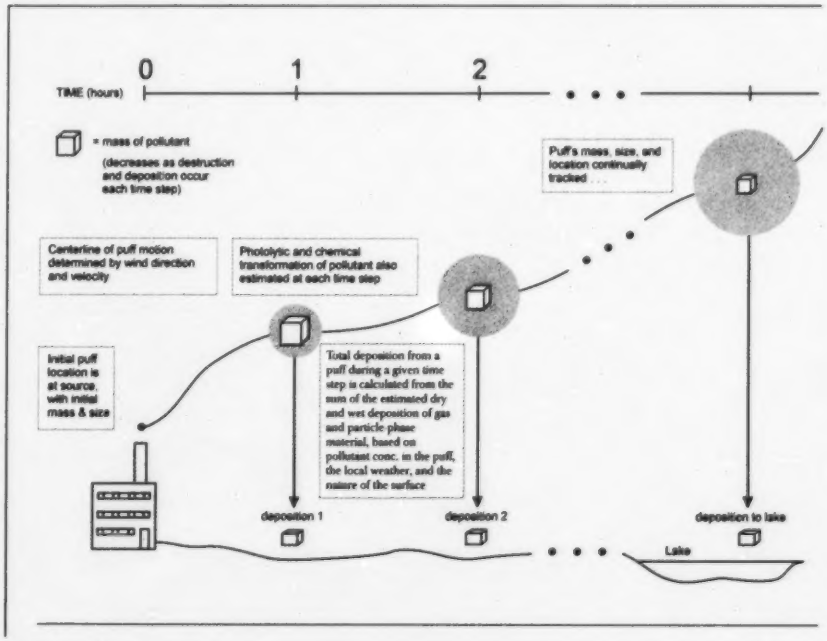
3 HCB has an extremely long atmospheric lifetime (~ years) and is generally believed to be globally distributed. Therefore, an analysis which considered only U.S. and Canadian inventories of this contaminant would be insufficient; rather, a global inventory and modeling effort would likely be necessary. Since the current effort is limited to U.S. and Canada, HCB was eliminated from consideration in the current phase of this project.

4 The U.S. National Toxics Inventory gives data only for a group of PAHs ("16-PAH"). The Canadian inventories for PAHs contain some individual PAHs, such as benzo(a)pyrene and anthracene. The two inventories cannot be combined in a straightforward manner; thus, PAHs have not been included in the current phase of this project.

5 Elemental gaseous mercury is similar to HCB in that it is believed to have an atmospheric lifetime of approximately 2 years. However, reactive gaseous mercury (RGM) (e.g. $HgCl_2$) has a much shorter atmospheric lifetime, as it is deposited very efficiently. As a result, atmospheric deposition of mercury may be dominated by the relatively short-range phenomena associated with RGM. Thus, a substantial part of the mercury deposition in the Great Lakes may come from sources in the U.S. and Canada. Therefore, it may be possible to perform a useful modeling study based primarily on U.S. and Canadian inventories. However, this hypothesis would have to be evaluated in any investigation. Such an analysis would require incorporation of a suitable method for including "global background" contributions.

6 Source categories are particular processes, e.g., municipal waste incineration, coal combustion, cement production, copper smelting, etc.

Figure 1 **Lagrangian Puff Air Transport and Deposition Model**

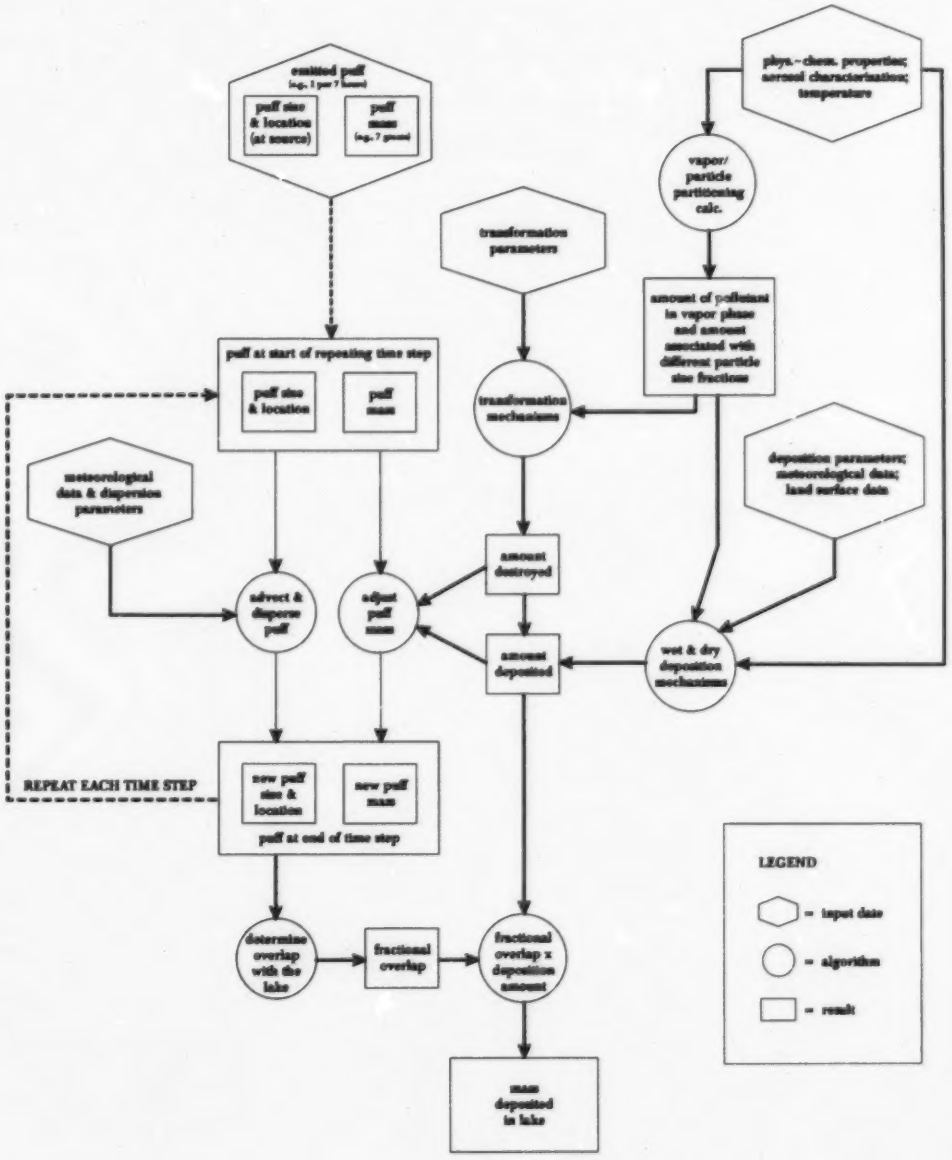

0
1
2
TIME (hours)
= mass of pollutant
(decreases as destruction and deposition occur each time step)
Puff's mass, size, and location continually tracked . . .
Centerline of puff motion determined by wind direction and velocity
Photolytic and chemical transformation of pollutant also estimated at each time step
Initial puff location is at source, with initial mass & size
Total deposition from a puff during a given time step is calculated from the sum of the estimated dry and wet deposition of gas and particle phase material, based on pollutant conc. in the puff, the local weather, and the nature of the surface
deposition 1
deposition 2
deposition to lake
Lake

For the current simulations, output from NOAA's Nested Grid Model (NGM) is being used. The NGM — a primitive-equation meteorological simulation model — takes weather-related observations and uses these data to estimate meteorological conditions existing between the observations (spatially and temporally). The data provided to HYSPLIT from the NGM include wind speed and direction, amount and type of precipitation, temperature, and humidity, as well as other meteorological data.[7]

HYSPLIT was chosen for this analysis for several reasons, including the following: (a) meteorological data necessary to drive the model were readily available for the period 1990-1999; (b) the model is computationally efficient - as it is designed for operational use - allowing year-long simulations to be performed practically; (c) the model and associated methodology have been specifically tailored to provide source/receptor information, a feature not commonly found in most fate and transport models; and (d) the model has been successfully applied in the past to simulate several of the compounds being considered here.

7 Gridded model outputs have been archived at a spatial resolution of 180 km (112 miles), with determinations at ten (10) vertical levels up to a height of 5,000 meters (16,400 feet) in altitude, with a temporal resolution of two hours.

Figure 2 Flow Chart of HYSPLIT Program


emitted puff
puff size & location (at source)
puff mass
phys.-chem. properties; aerosol characterization; temperature
vapor/ particle partitioning calc.
transformation parameters
amount of pollutant in vapor phase and amount associated with different particle size fractions
puff at start of repeating time step
puff size & location
puff mass
transformation mechanisms
deposition parameters; meteorological data; land surface data
meteorological data & dispersion parameters
amount destroyed
advect & disperse puff
adjust puff mass
amount deposited
wet & dry deposition mechanisms
REPEAT EACH TIME STEP
new puff size & location
new puff mass
puff at end of time step
determine overlap with the lake
fractional overlap
fractional overlap x deposition amount
mass deposited in lake
LEGEND
= input data
= algorithm
= result

The methodology used in this study has been developed in a series of studies performed previously (Cohen *et al.*, 1997ab, 1995; Commoner *et al.*, 1998). The simulation of atmospheric fate of a selected contaminant includes provision for vapor/particle partitioning, wet and dry deposition, reaction with the hydroxyl radical ($OH^{\cdot}$), and photolysis. [8]

It must be noted that other models could be used to perform this type of analysis. Indeed, the EPA has used the Lagrangian model RELMAP to simulate dioxin and cadmium fate and transport in the U.S. and is using an Eulerian framework (Models-3) to simulate atrazine transport and deposition to Lake Michigan.

6.3.3 Evaluation of Modeling Results

The modeling results will generally be evaluated by comparison with the two types of available primary monitoring data — measurements of atmospheric ambient concentrations and wet deposition. The availability of ambient atmospheric monitoring data is somewhat limited for many pollutants of concern in the Great Lakes; however, for the pollutants and time periods selected for this study, sufficient data exist for limited model evaluation purposes.

Given the substantial uncertainties in the emissions inventories and the fate and transport modeling - and sometimes in the ambient measurements themselves — it is not expected that model estimates will precisely match ambient measurements. Reasonable agreement with ambient measurements was found in previous work on dioxin and atrazine (Cohen *et al.*, 1995, 1997ab; Commoner *et al.*, 1998), and it is anticipated that satisfactory results will be obtained in the present analysis. A comparison of the ambient measurements with the model predictions will be presented to provide some context within which to understand the relative degree of matching. If there are significant differences, their potential reasons will be hypothesized and attempts to reconcile the discrepancies will be made.

Despite the uncertainties inherent in this work, it is anticipated that the results will be useful in the discussion of strategies to reduce loadings to the lakes from particular sources and source regions.

6.3.4 Uncertainties

There are substantial uncertainties involved in this analysis. Emissions inventories and the fate and transport simulation of the compounds studied in this project have not yet been well characterized by the scientific and/or regulatory community. Throughout the work, attention is being paid to this central limitation, and attempts continue to be made to provide qualitative and/or quantitative estimates of the magnitude of the uncertainties involved. Where possible, suggestions will be offered on areas of research and/or data collection that are critically needed to reduce uncertainties. Despite the uncertainties inherent in this work, it is anticipated that the results will be useful in the discussion of strategies to reduce loadings to the lakes from particular sources and source regions.

6.3.5 Summary of Methodology

Emissions inventories for the U.S. and Canada are being combined with an atmospheric model (HYSPLIT) to estimate the fate and transport of emitted pollutants, including deposition to each of the Great Lakes. Existing ambient monitoring data are being identified and assembled for use in evaluating the modeling results. For each compound, the modeling predictions of ambient air concentrations and wet deposition will be compared against available actual measurements. The simulation time periods chosen for this project are the following [9]:
(a) dioxin - 1996, full year; (b) atrazine - 1991, March-July; and (c) cadmium - 1993, full year.

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8 The current work for dioxin represents an update on previous work (Cohen *et al.*, 1997a, 1995; Commoner *et al.*, 1998) in the following ways: (a) use of more complete and up-to-date emissions inventories for the U.S. and Canada; (b) more monitoring data are available, allowing a more rigorous evaluation of the model results; (c) use of an updated version of the HYSPLIT model, reflecting numerous incorporated refinements; (d) substantial additional effort is being directed towards the visual display of model output; and (e) results for the Great Lakes are being estimated for 1996 (as opposed to 1993).

9 The decision regarding which time period to simulate revolved around a consideration of the following: (a) availability of adequate inventory information; (b) availability of ambient monitoring data for model evaluation; and (c) availability of meteorological data necessary to drive the model. No one year or time period perfectly satisfied all criteria for a given pollutant, but it is believed that the time periods chosen are reasonable, given the limitations in the availability of data. For example, at the time this project began, a binational atrazine inventory was only available for 1991. Moreover, the most substantial ambient monitoring data set was available for 1990-1991. Thus, 1991 was the logical (and really only) choice feasible for modeling this pollutant. Similar considerations apply to the other pollutants.

6.4 DIOXIN: APPLICATION OF THE COMPREHENSIVE MODELING TECHNIQUE

The polychlorinated dibenzo-*p*-dioxins and dibenzofurans pollutant group (PCDD/Fs) contains several potent carcinogens and powerful endocrine disruptors.[10] The comprehensive modeling technique is being applied to investigate the transport and deposition of dioxin from sources in the United States and Canada to the Great Lakes. In the discussion that follows, preliminary results are presented, including emissions inventories and the results of the fate and transport modeling.[11]

6.4.1 Case-Study Examples of the Calculations

As an introduction, results for two illustrative case-studies will be presented. In these case studies, emissions of dioxin from two different metropolitan regions, Hamilton, ON and St. Louis, MO-IL, are estimated, and their impact on atmospheric deposition to each of the Great Lakes is considered.

Estimated emissions from each of the metropolitan areas are presented in Table 5. The total emissions from the Hamilton area are estimated to be on the order of 30 grams TEQ/year.[12] For the St. Louis area, the emissions are estimated to be on the order of 133 grams TEQ/year.[13]

For both areas, metallurgical processes are the largest emissions category. Significant emissions also are contributed by waste incineration processes. Emissions from fuel combustion are relatively insignificant for both areas.[14] Rough estimates of the uncertainty in the emissions estimates are presented in Table 5. It can be seen that there is approximately a factor of 3 uncertainty on either side of the mid-range emissions estimates. The emissions inventories used in this analysis are discussed in more detail in section 6.4.2.

10 PCDD/F's will be referred to as "dioxin" in this chapter.

11 Work on this pollutant, as well as atrazine and cadmium, is ongoing, and a more complete report on all three pollutants anticipated toward the end of 1999.

12 TEQ (Toxic Equivalents) is a weighted average amount of dioxins/furans which takes into account the relative toxicity of the various forms of these compounds in a given mixture.

13 The Environment Canada inventory used in this work is for 1995, so the estimates for Hamilton, Ontario are most representative of 1995 emissions. The U.S. inventory used in this work is for 1996, and so the St. Louis estimates are most representative of emissions for 1996.

14 The relative importance of different source categories varies throughout different regions in the United States and Canada. In the inventories used in this analysis, waste incineration is estimated to be have higher overall emissions than metallurgical processes. Thus, this particular example is not representative of the overall emissions pattern of either nation.

Table 5 Estimated Dioxin Air Emissions for the Hamilton and St. Louis Metropolitan Areas

	Emissions (grams TEQ/year) *(the low-range and high-range estimates are given in parentheses below the mid-range estimate)*			
Metropolitan Area and Inventory Year	**Waste Incineration**	**Metallurgical Processes**	**Fuel Combustion**	**Total**
Hamilton (ON) 1995	4.2 *(1.3 - 13)*	25 *(8 - 80)*	0.50 *(0.16 - 1.6)*	30 *(10 - 95)*
St. Louis (MO,IL) 1996	33 *(10 - 100)*	99 *(33 - 310)*	1.5 *(0.5 - 4.6)*	133 *(42 - 420)*

Table 6 Model-Estimated Dioxin Transfer Coefficients from Hamilton and St. Louis to the Great Lakes

	Transfer Coefficients (dimensionless) (fraction of emissions predicted by the modeling to be deposited in a given lake; average value for all sources in the Metropolitan region, on a TEQ basis)				
Metropolitan Area	**Lake Ontario**	**Lake Erie**	**Lake Michigan**	**Lake Huron**	**Lake Superior**
Hamilton (ON)	3.6%	0.92%	0.40%	1.4%	0.40%
St. Louis (MO, IL)	0.16%	0.32%	1.5%	0.74%	1.0%

The estimated efficiencies of transfer of emissions from each of the case-study areas to each of the Great Lakes through the atmospheric deposition pathway are presented in Table 6.[15] For example, it is estimated that approximately 3.6% of the dioxin emitted into the air in the Hamilton area will be deposited in Lake Ontario over the course of a year. Due to the proximity of Hamilton to Lake Ontario, this transfer coefficient is higher relative to that for the other Great Lakes. For emissions from the St. Louis area, the largest transfer coefficient is 1.5%, to Lake Michigan, the closest Great Lake. Generally, the larger the lake, the higher the transfer coefficient will be, as there is a greater surface area for atmospheric deposition. However, the distance of the source from the lake and its orientation relative to the direction of prevailing winds play a major role as well.

The final step in this analysis is the use of the estimated transfer coefficients to assess the atmospheric deposition impacts of the emissions on the Great Lakes. This is done by multiplying the emissions by the model-estimated transfer coefficients.[16] Results of this multiplication are presented in Table 7 and are schematically depicted in Figure 3 (see page 133). Thus, for example, of the 130 grams TEQ/year emitted from the St. Louis area, 1.5% - or about 2 grams TEQ/year - are deposited in Lake Michigan. Lesser amounts are deposited in the other Great Lakes from this source area. Analogously, the Hamilton area contributes approximately 1.1 grams TEQ/year to Lake Ontario, and lesser amounts to the other Great Lakes. In this example, due to the importance of metallurgical processes in the estimated emissions, this source category contributes the largest amount of dioxin from these source areas to the Great Lakes.

Dioxin emitted to the atmosphere from any source is subject to dispersion (dilution) in the atmosphere, transformation (e.g., chemical reactions), and deposition to the earth's surface. These phenomena all tend to reduce the concentrations at greater and greater distances from the source. However, for dioxin, this dilution factor is not of such significance that regional and long range transport can be ignored. This example shows that emissions from outside the Great Lakes basin can be as or more significant than emissions from within the basin.

Dioxin emitted to the atmosphere from any source is subject to dispersion . . . These phenomena all tend to reduce the concentrations at greater and greater distances from the source. However, for dioxin, this dilution factor is not of such significance that regional and long range transport can be ignored.

In the following sections, this type of analysis is extended to other source regions in the United States and Canada.

6.4.2 Emissions Inventories for Dioxin

The starting point of the analysis is an emissions inventory. For the U.S., a 1996 dioxin emissions inventory prepared by the Center for the Biology of Natural Systems (CBNS) at Queens College N.Y. has been utilized. This 1996 inventory was used in an analysis of transport and deposition of PCDD/F to dairy farms in Vermont and Wisconsin (Commoner *et al.*, 1998). Built from a previously-prepared 1993 inventory[17], an attempt was made in this inventory to update the emissions from 1993 to 1996, to include several new source categories, and estimate

15 These estimates are based on the results of atmospheric modeling, discussed below.

16 There are many different dioxin molecules (congeners), each with a different toxicity and atmospheric behavior. Since there are different congener emissions profiles from each source, the actual calculation is done source by source, congener by congener. The overall, average results, on a TEQ basis, are summarized here.

17 An earlier version of the U.S. inventory, for the year 1993, was developed at CBNS during 1994 — 1995 in conjunction with an analysis of PCDD/F transport and deposition to the Great Lakes (Cohen *et al.*, 1995; 1997a). This 1993 inventory did not include a number of the source categories that were later included in the 1996 inventory. Area sources also were aggregated at the state/province and metropolitan area level. The earlier inventory was designed to be somewhat consistent — where appropriate — with the U.S. EPA Dioxin Reassessment Inventory (U.S. EPA 1994).

Table 7 **Atmospheric Deposition of Dioxin to the Great Lakes Arising from Air Emissions from the Hamilton and St. Louis Metropolitan Regions**

		Atmospheric Deposition to the Great Lakes (grams TEQ/year)				
Metropolitan Area	Source Category	Lake Ontario	Lake Erie	Lake Michigan	Lake Huron	Lake Superior
Hamilton (ON)	incineration	0.15	0.039	0.017	0.061	0.017
	metallurgical	0.91	0.24	0.10	0.36	0.10
	fuel combustion	0.02	0.0047	0.0021	0.0073	0.0021
	total	**1.1**	**0.28**	**0.12**	**0.43**	**0.12**
St. Louis (MO,IL)	incineration	0.05	0.11	0.48	0.25	0.34
	metallurgical	0.16	0.32	1.5	0.73	0.98
	fuel combustion	0.0023	0.0047	0.022	0.011	0.015
	total	**0.21**	**0.43**	**2.0**	**0.99**	**1.3**

emissions with a higher degree of spatial resolution. Consistency with a contemporaneous U.S. EPA inventory (U.S. EPA, 1998), where appropriate, was sought.

For Canada, a dioxin emissions inventory for 1995 prepared by Environment Canada and the Canadian Federal-Provincial Task Force on Dioxins and Furans has been used (Environment Canada *et al.*, 1999). Additional assistance in gridding the inventory for model application was provided by Environment Canada.

Overall summaries of the inventories are used to generate the binational emission map for dioxin (Figures 4 and 5 on pages 134 and 135). In Figure 4, the total emissions per county in the U.S. and in 50-100 km grid cells in Canada are mapped. Because the counties and grids are different sizes, the "areal density of emissions" has been mapped, i.e., the emissions for each locale (county or grid) are divided by the area of that locale.

The resulting units are grams TEQ per square kilometer per year, analogous to an emissions flux. In Figure 5, the total emissions for each state and province have been mapped as a percentage of the total emissions for the U.S. and Canada.

Maps of emissions from a few selected individual source categories include municipal waste incineration (Figure 6, page 136), medical waste incineration (Figure 7, page 137) and cement kilns burning hazardous waste and other alternative fuels (Figure 8, page 138). In these maps, which represent point sources, the emissions amount itself is mapped; the amount is *not* divided by the area and is represented by a circle of a particular size and color.

There are significant uncertainties in the estimation of dioxin emissions in the U.S. and Canada, because the number of actual sources sampled is very limited, and many important source categories appear poorly characterized. While the information available appears adequate to generate a first estimate of source/receptor linkages, further resources dedicated to improvement of emission inventories is crucial to improve the accuracy of this modeling methodology.

The dioxin inventories are currently being assessed for their degree of completeness in considering all significant emission sources. Preliminary results include the following:

- the U.S. inventory does not contain estimates for emissions from residential or commercial coal combustion, magnesium manufacturing, or small commercial incinerators;
- the Environment Canada emissions inventory for PCDD/F does not include backyard burning of residential waste, a potentially significant source; and
- neither the U.S. nor the Canadian PCDD/F inventories contain estimated emissions for open-burning of PVC-coated wires (e.g. structure and vehicle fires), asphalt production, landfill fires, combustion of landfill gas in venting or energy reclamation systems, coke production, combustion of leaded gasoline in on-road and off-road vehicles and aircraft, and petroleum refining operations.

Other shortcomings may exist in the PCDD/F inventories, and an attempt is being made to further correct or at least qualitatively discuss these limitations. In addition, in some cases, it is known that there have been significant changes in estimated emissions from particular sources and source categories since the inventories used in this analysis were compiled. For example, it is estimated that emissions from the municipal waste incinerator in Levis, Quebec (adjacent to Montreal) dropped from 61.8 grams (2 ounces) TEQ/year to less than one gram TEQ per year in Fall 1998, as a result of renovations made at the facility (Environment Canada, 1999). Thus, it is important to recognize that the inventories being used are intended to be representative of the modeling period chosen and do not necessarily reflect the current situation.

6.4.3 Generalized Fate and Transport Modeling of Dioxin

The HYSPLIT model was used to simulate the fate and transport of emitted dioxin from sources in the United States and Canada. Examples of the general results of this modeling have been summarized in transfer coefficient maps for overall dioxin TEQ for lakes Superior and Ontario (Figures 9 and 10, pages 139-140). These transfer coefficient maps are *independent* of the actual emissions. They only describe the relative efficiency of transport and deposition between each *location* on the map and the indicated receptor. A useful way to think about these maps is to consider that they represent the relative depositional impact on the given receptor from each point on the map *if the emissions were uniformly equal everywhere in the modeling domain.*

In Figure 9, for example, between 0.013 - 0.021 (1.3 - 2.1%) of any dioxin emissions that would be emitted within the red area would be deposited in Lake Superior. At the low end of the range (the yellow area), the fraction of dioxin emissions deposited is less than 0.003 (< 0.3%). Again, this map is not related to the actual emissions, but solely depicts the model-estimated ability of the atmosphere to carry emissions from various source locations and deposit them in the indicated lake.

The maps generally show the influence of the prevailing winds from the west and southwest, as the efficiency of transport from those directions is generally greater than for other directions. It is also evident that while the transfer coefficients diminish with distance from a given lake, they do not drop so precipitously that contributions from regional and long-range sources can be considered insignificant. Note that the transfer coefficient map will be different for each congener or mix of congeners considered, and for each receptor considered (a "congener" is a particular dioxin species; there are a total of 210 different dioxin congeners - see footnote 16). These maps were prepared

While the information available appears adequate to generate a first estimate of source/receptor linkages, further resources dedicated to improvement of emission inventories is crucial to improve the accuracy of this modeling methodology.

assuming a mix of congeners typical of the average mix of congener emissions in the U.S./Canadian emissions inventory. In practice, these maps are only created as examples of the calculation, and the myriad variations are handled computationally.

6.4.4 Evaluation of the Dioxin Modeling Results

In order to evaluate the overall validity of the modeling results, the modeling predictions at specific locales can be compared against ambient measurements at those locations. Ambient dioxin measurements in the U.S. and Canada have been reviewed by Cohen (1998). For dioxin, in 1996, 30-day ambient rural air measurements at two sites each in Vermont and Wisconsin (Commoner *et al.*, 1998), and one site in Connecticut are available, as are 48-hour samples at several rural sites in Canada (Dann, 1998). Other rural short-term (24-48 hour) measurements are potentially available as well in Mississippi (Fiedler *et al.*, 1997), Ohio (Wagrowski and Hites, 1997), and Vermont (Agency of Natural Resources, 1996). There are no direct measurements of dry deposition of PCDD/F for the time periods or regions of interest. Thus, dry deposition estimates for PCDD/F are typically inferred from ambient concentration measurements. The only wet deposition measurement program in North America appears to be that sponsored by the Ontario Ministry of Environment. Wet deposition data for PCDD/F for 1996 from a semi-rural site in Dorset, Ontario are being sought.

The dearth of ambient monitoring data for PCDD/F does reduce the potential for model evaluation, a significant limitation of this or any other PCDD/F modeling effort. Additional resources should therefore be devoted to measurements of dioxin ambient air concentrations and deposition. Other ambient air and precipitation data for dioxin will be incorporated into the analysis as they become available.

In recent studies (Cohen *et al.*, 1995; Commoner *et al.*, 1998), predicted dioxin concentrations using this methodology were found to be encouragingly close to ambient measurements; most predictions were matched by the measurements within the estimated uncertainties in each. In the present study, the relative agreement has been found to be comparable to that in the previous investigation. Model evaluation results are presented in a freestanding report on this project.

. . . the most significant sources of deposition to Lake Superior, accounting for near 40 percent, are located between 400 and 700 kilometers (250 and 435 miles) distant, whereas, in the case of Lake Ontario, approximately 35 percent of the deposition is from sources from 0 to 20 kilometers (0 to 12.5 miles) from the shoreline.

When monitoring and modeling are undertaken as complementary activities, the value of each is immeasurably increased. Ambient measurements are essential for model evaluation and hence model viability. At the same time, monitoring everywhere, all the time is not feasible. Modeling can help to fill in the spatial, temporal, and phenomenological gaps in the monitoring program, interpret available ambient measurements, refine existing monitoring programs, design new monitoring programs, and theoretically predict the impacts of different proposed courses of future action. Without both monitoring and modeling activities being undertaken in a complementary manner, the utility of each is decreased.

6.4.5 Source-Receptor Relationships for the Atmospheric Deposition of Dioxin to the Great Lakes Arising from Emissions in the U.S. and Canada

The emissions inventory data have been combined with the generalized fate and transport results to estimate source-receptor relationships between the sources in the inventory and each of the Great Lakes. Maps showing the geographical distribution of contributions of atmospheric deposition to Lake Superior and Lake Ontario are presented in Figures 11-14 (pages 141-144). Mid-range (geometric mean) estimates of emissions were used to generate these maps. In Figures 11 and 13, the areal density of deposition contribution is mapped (µgrams TEQ/km^2-year), and in Figures 12 and 14, the total contributions for each state and province are mapped as a percent of the total estimated deposition.

While maps for deposition to all the individual lake basins are available, these two were chosen for this summary chapter to contrast a relatively undeveloped shoreline (Lake Superior) with an extensively developed one (Lake Ontario). As might be expected, influential sources of persistent toxic substances to Lake Superior are typically at a greater distance than the more localized sources affecting Lake Ontario. Indeed, in the case of Lake Superior, sources as far south as St. Louis are having a significant effect on deposition to the lake, while the large urban centers immediately adjacent to Lake Ontario are responsible for a significantly greater deposition to that lake.

Overall graphical summaries of the relative contributions from different distances and source categories are presented in Figures 15, 16, and 17 (pages 145-146). Figure 15 notes that the most significant sources of deposition to Lake Superior, accounting for near 40 percent, are located between 400 and 700 kilometers (250 and 435 miles) distant, whereas, in the case of Lake Ontario, approximately 35 percent of the deposition is from sources from 0 to 20 kilometers (0 to 12.5 miles) from the shoreline.

Figure 16 shows that the percent of deposition for each of the lakes arising from emissions in each of the states and provinces in the Great Lakes basin (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York, and Ontario) and the percent arising from the rest of the United States and Canada. These data are also presented in Table 8. It can be seen that on the order of 75% of the dioxin deposition to the Great Lakes arises from the Great Lakes states and provinces. However, for Lakes Superior and Huron, only about

25% of the deposition arises from states and province actually adjoining the Lake.

Figure 17 presents preliminary estimates of the contribution of specific source categories to the annual dioxin deposition flux (grams TEQ deposited per square kilometer of lake) to specific lake basins.

In order to summarize these results succinctly, the various source categories in the inventories were aggregated into three general categories: incineration, metallurgical processes, and fuel combustion. The estimated impacts (grams TEQ deposited to a given lake per year from each category) were divided by the area of the lake to get a flux (grams TEQ per km^2 per year)[18] This flux amount was then divided by the population of the source country to obtain a per-capita value for the contribution. On average, using 1995-1996 emissions inventory data, various types of incinerators were the major source category of dioxin deposition to the entire Great Lakes basin. Even on a per-capita basis, the U.S. contribution appears to be relatively large compared to the Canadian contribution[19], except for Lake Ontario, where the two are comparable.

18 This normalization by lake area was done so that the deposition contributions to the lakes could be compared on an equal basis. That is, all things being equal, there will be more atmospheric deposition (e.g., grams per year) to a large lake than a small lake (since the surface area for deposition is larger), but, a large and small lake will have the same atmospheric deposition flux (e.g., grams per year per square kilometer of lake).

19 Informal burning of waste (e.g., backyard trash burning) has not yet been included in the Canadian inventory, and its significance is not well understood presently. This omission may *partially* account for the U.S./Canadian difference.

On average, using 1995-1996 emissions inventory data, various types of incinerators were the major source category of dioxin deposition to the entire Great Lakes basin. Even on a per-capita basis, the U.S. contribution appears to be relatively large compared to the Canadian contribution, except for Lake Ontario, where the two are comparable.

It should be noted that this analysis has included only sources in the United States and Canada; sources in Mexico have not been considered. Unfortunately, a dioxin inventory for Mexico is not currently available. Given the distances involved, it is expected that the contribution of dioxin from Mexico to the Great Lakes will be relatively insignificant. However, this hypothesis will have to be verified through an extension of this comprehensive modeling analysis when an inventory for Mexico becomes available. Further extension of the analysis to yet additional countries might also be useful, but is expected to add relatively little to the analysis of the dioxin input to the Great Lakes; in any event, this hypothesis can be tested in future work.

Table 8 **Contribution of 1995/1996 Atmospheric Deposition of Dioxin to the Great Lakes from Great Lakes States and Provinces and from the Rest of the U.S. and Canada***

	Percent of Atmospheric Deposition of Dioxin to Lake Contributed by State or Province					
State or Province	Lake Superior	Lake Huron	Lake Michigan	Lake Erie	Lake Ontario	Average for Great Lakes
Illinois	16	11	36	6	4	15
Indiana	13	12	27	8	4	13
Michigan	10	17	7	11	4	10
Minnesota	9	3	3	1	1	4
New York	4	8	2	8	35	11
Ohio	7	17	4	37	15	16
Pennsylvania	2	3	1	5	8	4
Wisconsin	2	1	2	0.3	0.3	1
Ontario	6	4	1	2	7	4
Total for Great Lakes States and Provinces	69	75	83	78	79	77
Total for all other U.S. States	29	23	16	21	20	22
Total for all other Canadian Provinces	2	2	1	1	2	1
Total for all other U.S. and Canadian States and Provinces	31	25	17	22	21	23
Total	100	100	100	100	100	100

* Note: Sums may not appear exact because of rounding.

6.5 FINDINGS AND CONCLUSIONS

Preliminary Findings

This and earlier work confirm that:

- significant emissions of persistent toxic substances originate from a variety of different source types and a broad geographical range of locations;
- individual persistent toxic substances exhibit distinct behaviour in the atmosphere, with a wide range of estimated lifetimes/transport distances/re-emission rates, all of which must be accounted for in model development;
- for the contaminants under review in this report, dispersion, transformation, and deposition mechanisms generally serve to reduce quantities deposited as distance from the source increases; [For some other Binational Toxics Strategy pollutants, re-emission or re-volatilization (grasshopper effect) can significantly lengthen the effective transport distance and even cause an eventual accumulation at distances far from the source, in locales such as the Arctic.]
- on a source-by-source basis, all things being equal, nearby sources will generally have a greater depositional impact than more distant sources; [However, the number of sources will increase with increased distance from the receptor, offsetting the lowered depositional impact per source with the presence of more sources.]
- comprehensive models appear to have the capability to identify sources of specific persistent toxic substances to individual lakes in the Great Lakes basin and to quantify their associated deposition.

This project to date has revealed the following:

- For dioxin, it is estimated that approximately 75 percent of deposition to the five Great Lakes from air pathways originates from within the Great Lakes states and provinces.
- In considering sources of atmospheric deposition of dioxin to Lake Ontario, approximately 50 percent appears to originate from sources in close proximity to the lake, while the balance occurs from sources at a much greater distance (400-1500 km [250-930 miles]); a similar pattern occurs in deposition to Lake Erie and Lake Michigan.
- Regarding deposition to Lake Superior, transport of dioxin from outside the region is relatively more important (40 percent of deposition is from sources between 400 — 700 km (250 and 435 miles) distant, since there are few immediately adjacent upwind sources. This finding is also applicable to Lake Huron.
- The HYSPLIT model has demonstrated a capability to credibly link specific sources and source regions of a particular persistent toxic substance to quantified deposition in a particular Great Lake. The methodology used appears to yield determinations of reasonable accuracy with relatively moderate computational resource requirements.

To ensure more certainty in the application of this tool, useful additional activities would include:

- a further examination of the quality of the associated emissions inventories with subsequent appropriate upgrading;
- further testing and refinement of the fate and transport modules within the model;
- a more extensive ambient monitoring program in both air and water media to yield additional data for model evaluation purposes; and
- some further comparison with the methodologies, algorithms and outputs of other efforts, such as RELMAP and Models-3, as applied to some of these Binational Toxics Strategy (BTS) contaminants.

Preliminary Conclusions

Specific to the dioxin example outlined in this work, the board has shown that:

- a binational 'seamless boundary' base map of emissions inventories for dioxin can be prepared and presented in electronic and printed form;
- based on detailed work with dioxin and ongoing efforts for atrazine and cadmium, the NOAA HYSPLIT model can be used to develop transfer coefficients estimating the portion of emissions of those substances from specific locations across Canada and the United States that would be theoretically deposited in individual basins of the Great Lakes;
- applying the best available emissions inventories for these contaminants to the transfer coefficients so developed, quantities deposited in particular Great Lakes from specific point sources, source categories and discrete area sources can be estimated; and
- the overall modeling results for specific contaminants can be verified through comparison to concentration measurements in ambient air and precipitation.

The Implications of the Work to Date

The IAQAB, through its multiyear effort to enhance the understanding of atmospheric deposition to the Great Lakes, has supported development and demonstration of a powerful and efficient methodology for identifying specific sources and source regions of selected persistent toxic air emissions which are deposited in the Great Lakes. The methodology:

- utilizes emissions inventory data and an atmospheric fate and transport model to estimate the atmospheric deposi-

tion to the lakes from each emission source. The HYSPLIT model has been used in this work, although other models could also perform the required tasks.

- reinforces the need for a continental, systematic, and sustained approach to improved annual or biennial estimation of emissions, in order to allow modeling that will determine associated trends in deposition reductions and demonstrate progress achieved by control strategies. For successful application to all of the substances of concern in the Great Lakes, more accessible and comprehensive emission information, including the removal, where necessary, of current inventory confidentiality restrictions, is essential.
- systematic measurements of ambient air, precipitation, and water concentrations must be extended to provide information on long term trends of contaminant loadings to and concentrations in Great Lakes waters. These measurements would also facilitate additional model development and model evaluation and validation.
- although there is a large number of mandatory and voluntary control programs for persistent toxic substances on both sides of the border, it is difficult to assess their effectiveness in reducing emissions. This deficiency could be rectified by the Parties producing regular updates of emission inventories in a coordinated binational manner.

Recommendation

- **The IAQAB recommends that the International Joint Commission actively advocate, to the U.S. and Canadian governments, the coordinated use of this or a similar methodology to reexamine current control programs and to identify additional actions necessary to address the goals contained in the Great Lakes Water Quality Agreement and the associated Binational Toxic Strategy for the reduction of inputs of persistent toxic substances, particularly those transported via the atmospheric pathway.**

6.6 AFTERWORD: THE IAQAB AIR QUALITY WORKSHOP AT THE IJC BIENNIAL PUBLIC FORUM MILWAUKEE WI, SATURDAY, SEPTEMBER 25, 1999

6.6.1 Board Presentation

In addition to presenting the HYSPLIT modeling, the Board also reviewed another aspect of Annex 15 of the Great Lakes Water Quality Agreement, specifically the commitment of the governments of the United States and Canada, in co-operation with State and Provincial jurisdictions to '*develop, adopt and implement measures for the control of emissions of toxic substances and the elimination of... emissions of persistent toxic substances [that]...significantly contribute to pollution of the Great Lakes system.*'

The Board assessment of these activities included i) an electronic survey targeted at individuals involved in air quality management at state agencies; ii) review of US emissions at the county level of the approximately 30 compounds (see table 9) in the 1997 Binational Toxics Strategy and related control programs. The Binational Toxics Strategy pollutants are classified as Level I or Level II pollutants. (The Level I list is very similar to the Great Lakes Water Quality Board Critical Pollutants list of 1985- the Strategy can be regarded as an augmentation of Annex 15 of the GL Agreement). A compilation of Canadian control program descriptions and selected emissions information was also developed. Both the US county emissions document and the Canadian compilation are available at the IAQAB website *www.ijc.org/boards/iaqab*.

The response of states to the electronic survey was inadequate, notwithstanding some of the national commitments contained in the US segment of the Binational Toxics Strategy. A majority of the 48 states did not respond to repeated messages; useful responses received were less than 5% of the total sent. There was little evidence that the information sought was being assembled in any systematic way at that level of government. It was not apparent that the requirements of Annex 15 and the Strategy were being effectively communicated to states, particularly those outside the Great Lakes basin.

The balance of the Board research yielded information on programs targeted at specific source sectors, for example, projected emission reductions associated with recent US Clean Air Act regulations for municipal and medical incinerators. In Canada, under the ARET program, some quantification of benefits from specific actions was also available. Further detail on these programs is posted on the IAQAB website. Reductions, such as those achieved under the MACT (Maximum Available Control Technology) initiative in the US and the Strategic Options Plan program in Canada, are estimated in some cases. The cataloguing of this and other related information for the Level I and Level II contaminants proved a major undertaking; the Board report on U.S. emissions at the county level and related activities is in excess of 700 pages and growing. ***However, no systematic and comprehensive database on quantification of reductions of releases specific to BNS contaminants was located, precluding any comprehensive review of Annex 15 control outcomes and any further modeling work on any contaminants other than dioxin, cadmium and mercury.***

In the absence of a mechanism for the routine development of a binational inventory, the Board established a bilateral Emissions Inventory Working Group, consisting of individuals within Environment Canada, the Ontario Ministry of the Environment, USEPA and a few state agencies, to support development of inventories for three pollutants - dioxin, cadmium and mercury. The Group provided the basis for the development of a single map, in both digital and printed form, displaying dioxin emission information from both US and Canada, with similar presentations of cadmium and mercury emission data to follow.

In the U.S., the major source of emissions data is the National Toxics Inventory; its Canadian counterpart is the National Pollutant Release Inventory. While these initial efforts have merit, they also have several shortcomings. Sources are currently not well documented; little or no information on associated processes is offered; spatial and temporal resolution is not adequate for detailed analyses as, for example, sources are frequently being aggregated at the county level. The magnitude of unconsidered sources, such as rural residential refuse fires, is neither mentioned nor estimated. These inventories may support planning decisions for some contaminants, but in a majority of cases, they lacked sufficient detail to support the type of analysis attempted by the Board.

Further, while some states, such as California, actively collect, process and disseminate such information to the federal government, there are apparently no uniform requirements for such state submissions. The result is a severely skewed presentation of state based emissions information in the national inventory.

In Canada, the National Pollutant Release Inventory (NPRI), which considers releases into air, water and land, can support some analytical work, but it is not without deficiencies. For inclusion in the inventory, 10 tonnes of a specific toxicant must

. . . while some states, such as California, actively collect, process and disseminate such information to the federal government, there are apparently no uniform requirements for such state submissions. The result is a severely skewed presentation of state based emissions information in the national inventory.

be produced, processed or used at the facility. Major sources, for example mercury emissions from the coal fired utilities of Ontario Hydro, are not included, and there are few statements on the quality of the data. Of the 176 substances listed, only five are included within the Binational Toxic Strategy.

The Great Lakes also has a multilateral emissions inventory, the Great Lakes Regional Air Toxics Emission Inventory co-ordinated by the Great Lakes Commission . It currently contains 82 compounds from stationary point and area sources. The first regional inventory (for 1993) was first available in 1997; an updated version, including mobile source data and 1996 point source information should be released shortly. The information from the 1993 Air Toxics Inventory was forwarded to the USEPA so the Great Lakes component of the NTIS inventory should be very similar to the GL inventory.

Process level information is often maintained on a confidential basis causing some states to group the data on a county level. This would limit the utility of the inventory for modeling applications. The data or estimate sources are documented in the inventory and there is an effort to put relevant factors and production rates on the database.

Data are available only to the research community, while data summaries are available to the public via the Internet at *www.glc.org/air/air3.html*. The software to view the inventory may be downloaded from the Internet; users will also need Oracle software to manipulate the data. Binational co-operation has been achieved with the Ontario and the Canadian federal government; agencies from Texas, Louisiana and Quebec have all attended inventory organizing meetings. There is reason to believe that this inventory will be more closely linked to the BN Strategy that the other described herein would be.

The quality of available national inventories for specific BNS contaminants could be summarized into three categories. In the relatively "*good*" category (adequate for modeling and other detailed applications) are inventories for dioxin, mercury, and cadmium.

For those contaminants in the second category, emissions data are *indicative* only; a general sense of sources and source categories is provided for these contaminants, but significant gaps preclude modeling or other sophisticated analyses. Approximately 8 contaminants are in this category, including 1,4-dichlorobenzene, benzo[a]pyrene, anthracene, benzo[a]anthracene, benzo(g,h,i)perylene, perylene, phenathrene, and PAHs as a group.

For the great majority of the BNS contaminants, inventories must be significantly upgraded by the Parties and appropriate jurisdictional governments before comprehensive statements about progress toward virtual elimination and development of analyses needed for development of strategic and tactical guidance are possible.

For the remaining BNS contaminants, inventories are judged to be *inadequate* for the determination of emissions trends, let alone modeling source receptor relationships.

Some characteristics of a quality inventory include relative currency; representation of all significant sources; explicit quality control; estimates based on actual measurements as opposed to emissions factors; and public access to allow review and application.

The issue of public availability of emission data is of particular concern. For example, while data in the Canadian NPRI are available, only a few of the BNS pollutants are included and, as noted, not all significant sources are listed. Similarly, under the Great Lakes Air Toxics Emission Inventory, confidentiality issues in some instances result in emissions estimates at a county level rather than for particular point sources. ***It would be appropriate for the Commission to recommend that, in cases where facilities are using the external environment for waste disposal, information specific to the facility on the quantities so disposed of and related data on emission characteristics and process parameters should be made available to the public.***

In summary, the Board has located and processed emissions data, created a seamless boundary map of emissions from the US and Canada, and used these tools to determine and refine source/receptor linkages for dioxin deposition to the Great Lakes basin. Similar analyses for cadmium and mercury will be forthcoming. For the great majority of the BNS contaminants, inventories must be significantly upgraded by the Parties and appropriate jurisdictional governments before comprehensive statements about progress toward virtual elimination and development of analyses needed for development of strategic and tactical guidance are possible. ***The Parties, in support of the current binational agreements and strategies, should commit resources to support the preparation of a binational publically accessible database which includes the BNS contaminants and is capable of demonstrating progress on emission reductions and supporting the determination of source/receptor linkages.***

The Board also noted that models cannot be improved nor their outputs put in a suitable context without performance of systematic measurements of ambient air, precipitation, and water concentrations to validate the modeling and to determine and understand trends.

6.6.2 Panel Discussion and Public Comment

In the discussion that ensued, the following points were emphasized:

- the continuation of the modeling and mass balance work, considering tributary loadings, point, groundwater, sediment and atmospheric sources, should not be seen as an impediment to further regulation. Existing authorities should be aggressively applied and, if necessary, new authorities should be sought. For example, the original US Super-Fund Program did not consider bioaccumulation in fish as a basis for Superfund site designation. That regulation has now been changed to make bioaccumulation one of the criteria.

- During the workshop there were repeated references to Total Maximum Daily Loads (TMDLs). The TMDLs approach has been in the US Clean Water Act since 1972 - only recently has this approach been extended beyond conventional pollutants (phosphorus, BOD) to persistent toxic substances in a multipathway context.

- Another perspective on source related risk assessment was raised. Ten or 15 years ago, risk assessments considered only the inhalation pathway from one incinerator. Now it is understood that most of the associated risk lies with ingestion of dairy and meat products. The cumulative impact of 46,000 sources, which is apparent through the modeling approach, is considerably larger. It is unclear if the regulatory mechanisms in the U.S. and Canada today can accommodate this comprehensive approach.

- It was agreed that the clear authority to deal with bioaccumulation impacts is not currently established in the US. Less obvious authorities under all US legislation, for example, the Clean Water Act and its TMDL approach, requiring states to list threatened water bodies and promulgate TMDLs for persistent toxics, may provide some alternate mechanisms.

- Lake Michigan Mass Balance work has recently revealed the impact of urban plumes on waterbodies. For PCBs, about half of the deposition to Lake Michigan originates in the Chicago-Gary urban plume. This short range areal source also will require further attention.

- Chemicals having long lifetimes in the atmosphere will also prove very difficult to monitor in the absence of good quality global inventories, although recent research has linked Southern US soil samples of certain organo-chloride compounds to deposition in the Arctic using isomer differentiation techniques.

- Participants in the workshop stressed that modeling and inventory efforts should parallel and not displace further control programs, particularly for mercury from coal fired utilities and PAHs (benzo-a-pyrene) from the aluminum smelting sector.

Table 9 Binational Toxic Strategy Pollutants*

Level I Substances	Level II Substances
Aldrin/dieldrin	Cadmium and cadmium compounds
Benzo(a)Pyrene {B(a)P}	1,4-dichlorobenzene
Chlordane	3,3'-dichlorobenzidine
DDT (+DDD+DDE)	Dinitropyrene
Hexachlorobenzene (HCB)	Endrin
Alkyl-Lead	Heptachlor (+Heptachlor epoxide)
Mercury and mercury compounds	Hexachlorobutadiene
Mirex	(+Hexachloro-1,3-butadiene)
Octachlorostyrene	Hexachlorocyclohexane
PCBs	4,4'-methylenebis (2-chloroaniline)
PCDD (Dioxins) and PCDF (Furans)	Pentachlorobenzene
Toxaphene	Pentachlorophenol
	Tetrachlorobenzene (1,2,3,4- and 1,2,4,5-)
	Tributyl tin
	Plus PAHs as a group, including but not limited to:
	– Anthracene
	– Benzo(a)anthracene
	– Benzo(g,h,i)perylene
	– Perylene
	– Phenanthrene

*USEPA/Environment Canada "Canada-United States Strategy for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes" (1997)

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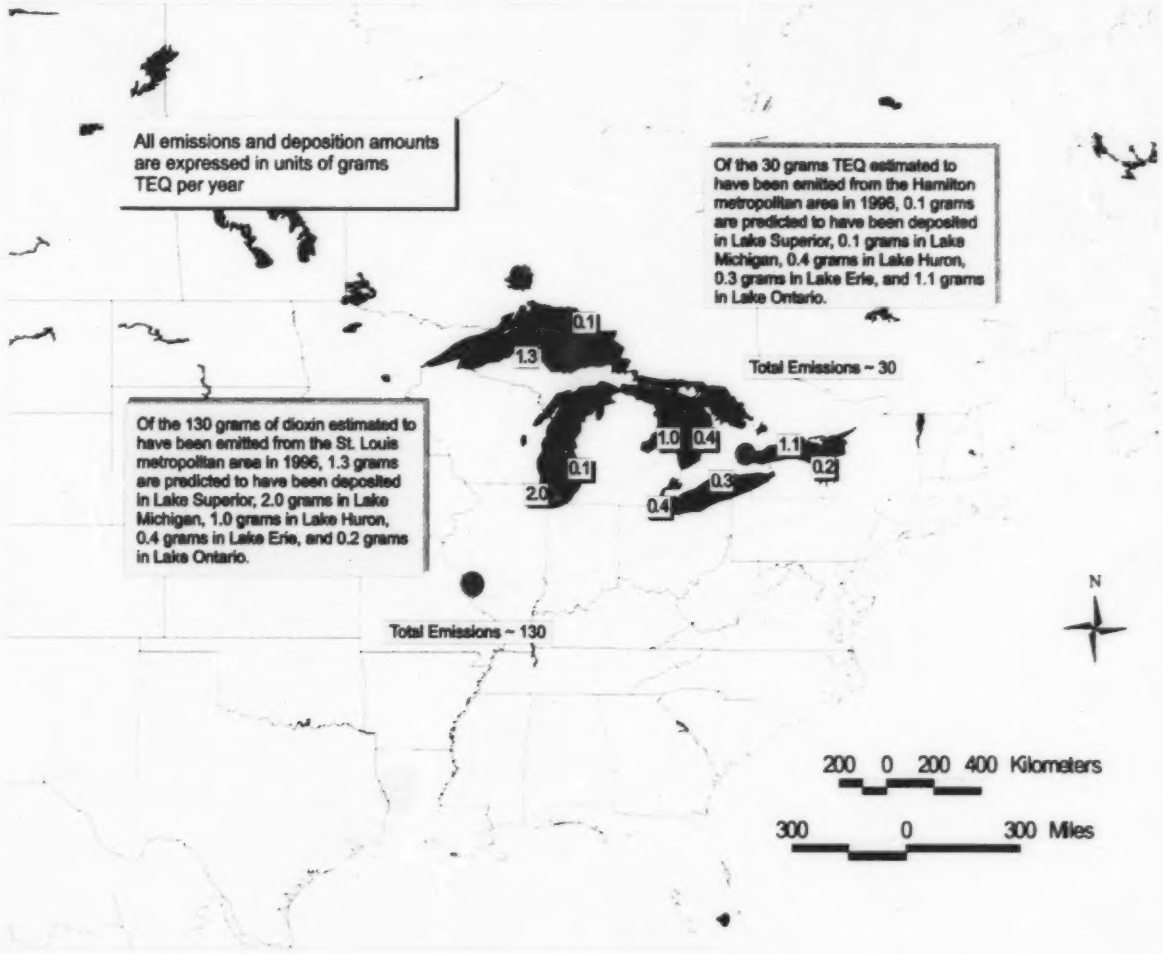
Figure 3 Illustrative Case Study Examples of Dioxin Modeling Results


All emissions and deposition amounts are expressed in units of grams TEQ per year
Of the 30 grams TEQ estimated to have been emitted from the Hamilton metropolitan area in 1996, 0.1 grams are predicted to have been deposited in Lake Superior, 0.1 grams in Lake Michigan, 0.4 grams in Lake Huron, 0.3 grams in Lake Erie, and 1.1 grams in Lake Ontario.
Total Emissions ~ 30
Of the 130 grams of dioxin estimated to have been emitted from the St. Louis metropolitan area in 1996, 1.3 grams are predicted to have been deposited in Lake Superior, 2.0 grams in Lake Michigan, 1.0 grams in Lake Huron, 0.4 grams in Lake Erie, and 0.2 grams in Lake Ontario.
Total Emissions ~ 130
0.1
1.3
1.0
0.4
1.1
0.2
0.1
2.0
0.3
0.4
N
200 0 200 400 Kilometers
300 0 300 Miles

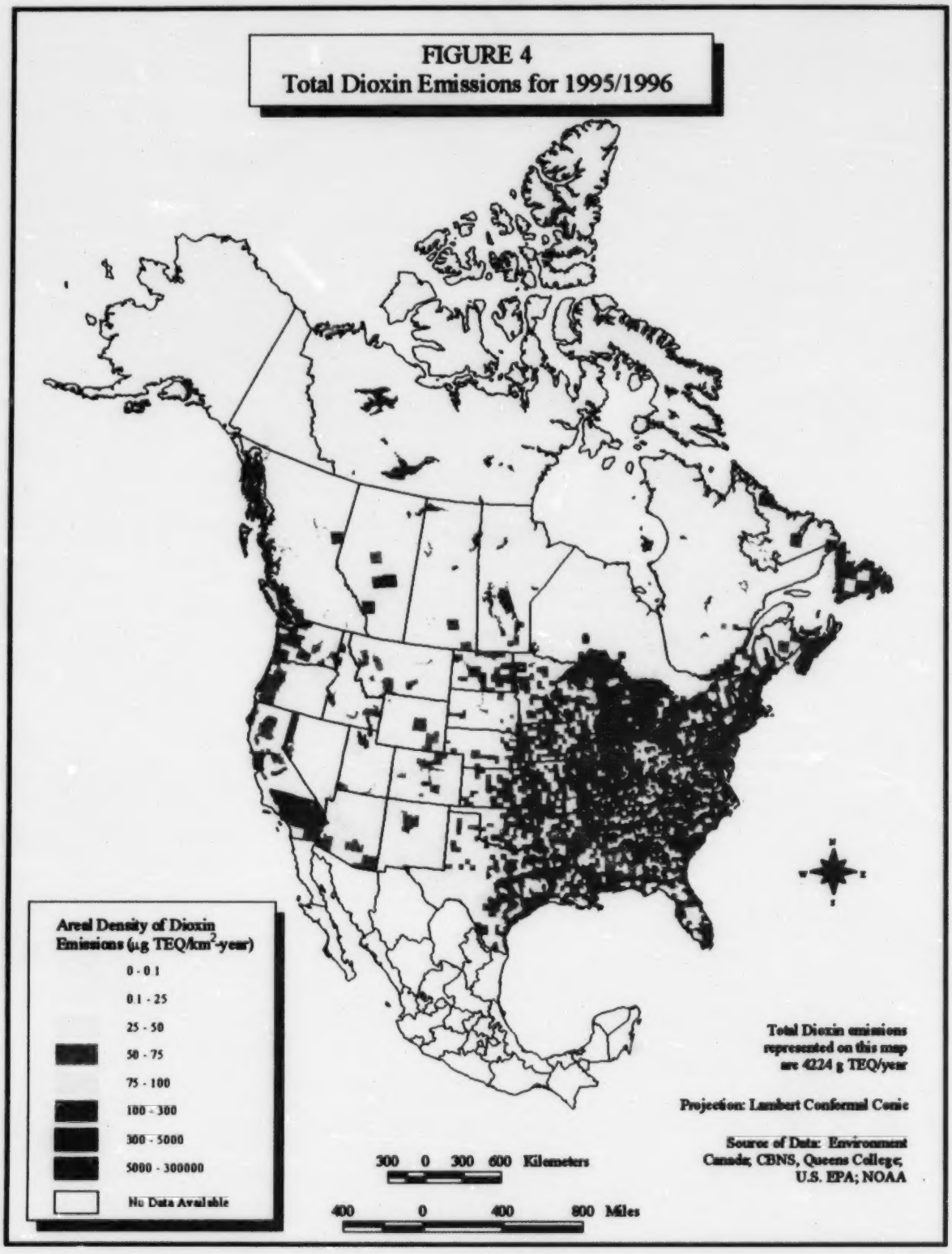


FIGURE 4
Total Dioxin Emissions for 1995/1996
Areal Density of Dioxin Emissions (µg TEQ/km²-year)
0 - 0.1
0.1 - 25
25 - 50
50 - 75
75 - 100
100 - 300
300 - 5000
5000 - 300000
No Data Available
300 0 300 600 Kilometers
400 0 400 800 Miles
Total Dioxin emissions represented on this map are 4224 g TEQ/year
Projection: Lambert Conformal Conic
Source of Data: Environment Canada; CBNS, Queens College; U.S. EPA; NOAA

FIGURE 5
Total Dioxin Emissions for 1995/1996
(Percent of total US/Canadian emissions from each State and Province)

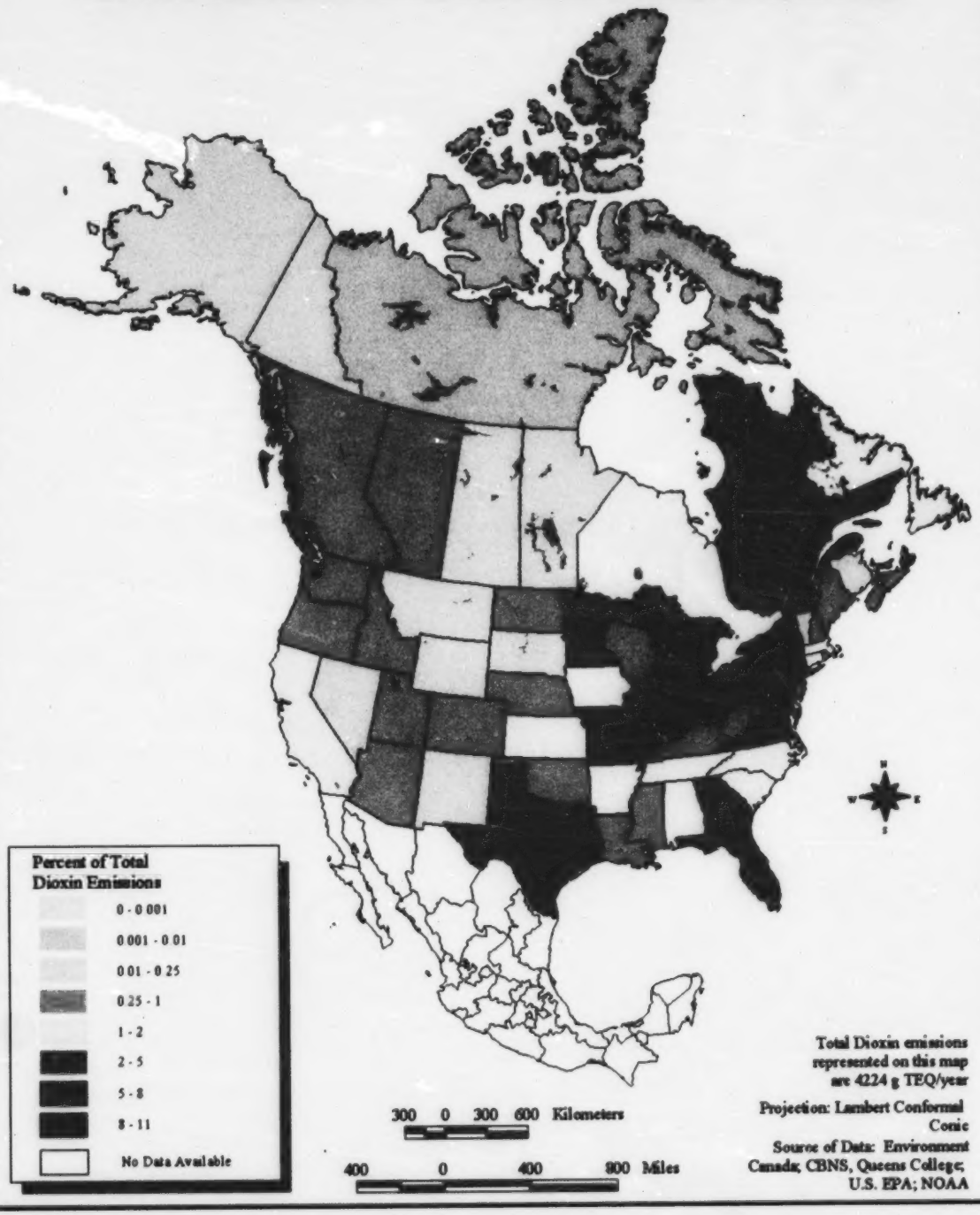

Percent of Total Dioxin Emissions
0 - 0.001
0.001 - 0.01
0.01 - 0.25
0.25 - 1
1 - 2
2 - 5
5 - 8
8 - 11
No Data Available
300 0 300 600 Kilometers
400 0 400 800 Miles
Total Dioxin emissions represented on this map are 4224 g TEQ/year
Projection: Lambert Conformal Conic
Source of Data: Environment Canada; CBNS, Queens College; U.S. EPA; NOAA

FIGURE 6
Total Dioxin Emissions for 1995/1996
- Municipal Solid Waste Incineration -
Dioxin Emissions (g TEQ/year)
-Municipal Solid Waste Incineration-
0 - 0.5
0.5 - 5
5 - 10
10 - 50
50 - 100
100 - 300
300 0 300 600 Kilometers
300 0 300 600 Miles
Total Dioxin emissions represented on this map are 2106 g TEQ/year
Projection: Lambert Conformal Conic
Source of Data: CBNS and Environment Canada
No Data for Mexico are available.

FIGURE 7
Total Dioxin Emissions for 1995/1996
- Medical Waste Incineration -

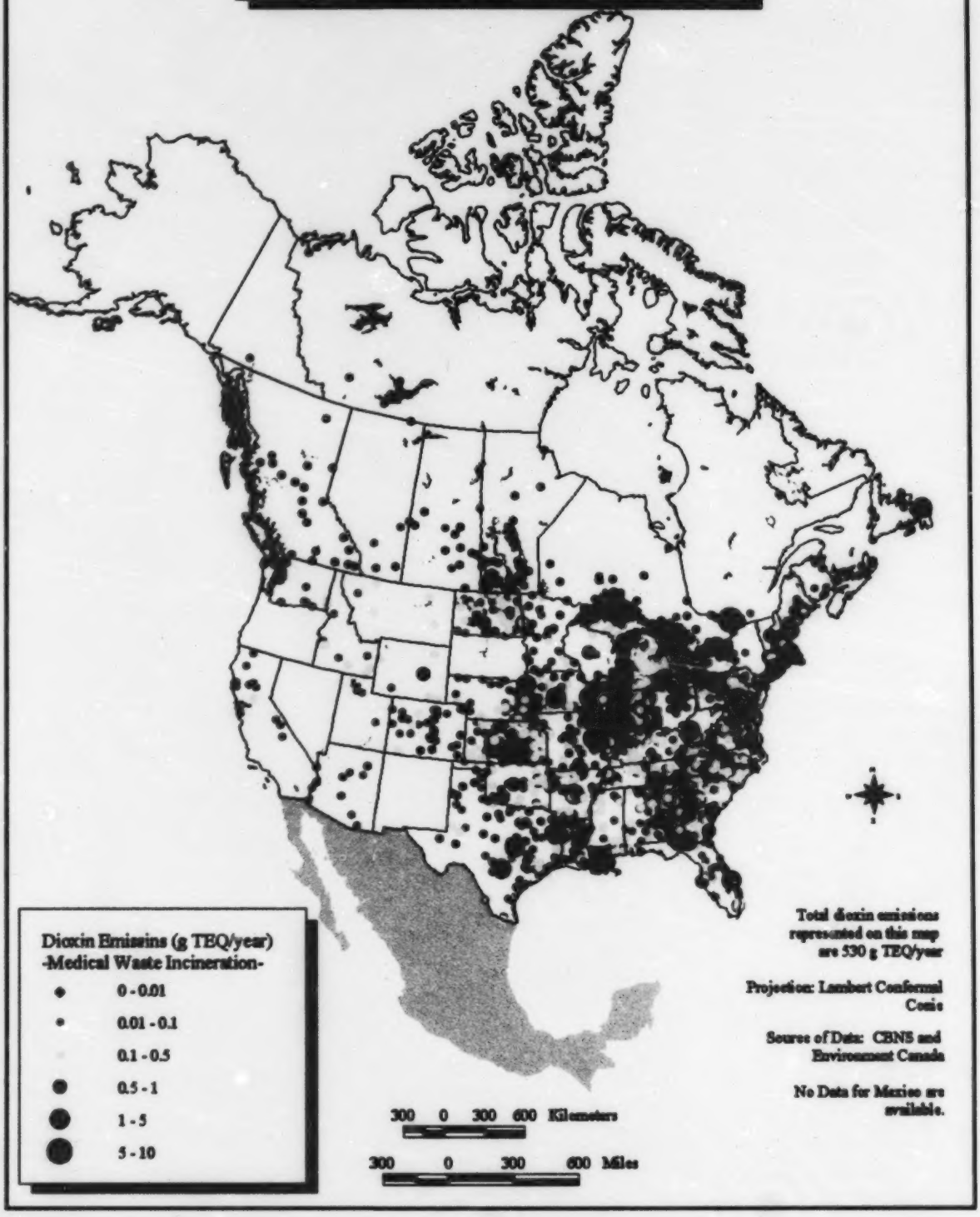

Dioxin Emissins (g TEQ/year)
-Medical Waste Incineration-
0 - 0.01
0.01 - 0.1
0.1 - 0.5
0.5 - 1
1 - 5
5 - 10
300 0 300 600 Kilometers
300 0 300 600 Miles
Total dioxin emissions represented on this map are 530 g TEQ/year
Projection: Lambert Conformal Conic
Source of Data: CBNS and Environment Canada
No Data for Mexico are available.

FIGURE 8
Total Dioxin Emissions for 1995/1996
- Cement Kilns (Burning Hazardous Waste and Alternative Fuels) -

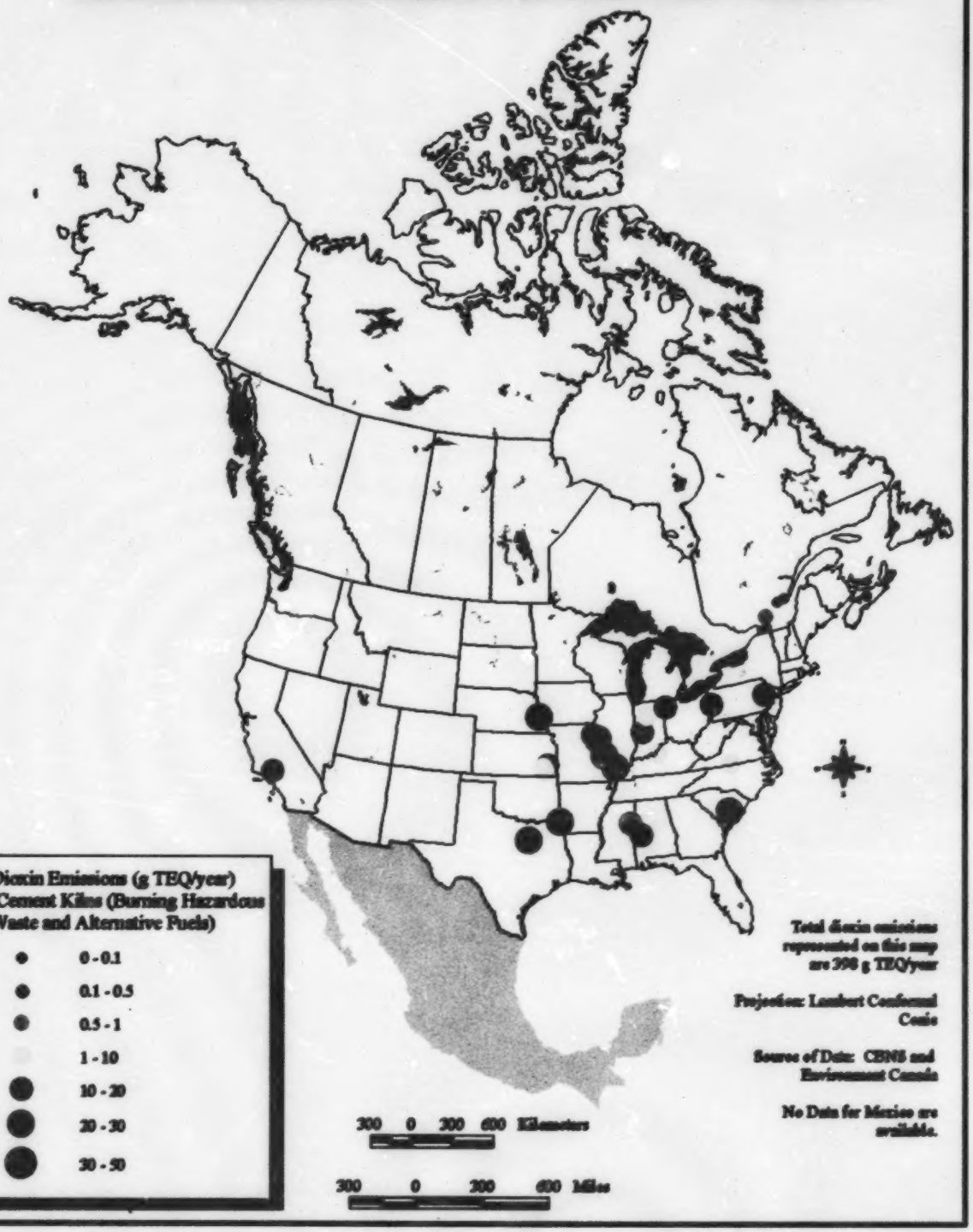

Dioxin Emissions (g TEQ/year)
-Cement Kilns (Burning Hazardous Waste and Alternative Fuels)
0 - 0.1
0.1 - 0.5
0.5 - 1
1 - 10
10 - 20
20 - 30
30 - 50
300 0 300 600 Kilometers
300 0 200 400 Miles
Total dioxin emissions represented on this map are 398 g TEQ/year
Projection: Lambert Conformal Conic
Source of Data: CEMS and Environment Canada
No Data for Mexico are available.

FIGURE 9
Fraction of 1996 Dioxin Emissions Deposited in Lake Superior
(grams TEQ deposited per year/grams TEQ emitted per year)

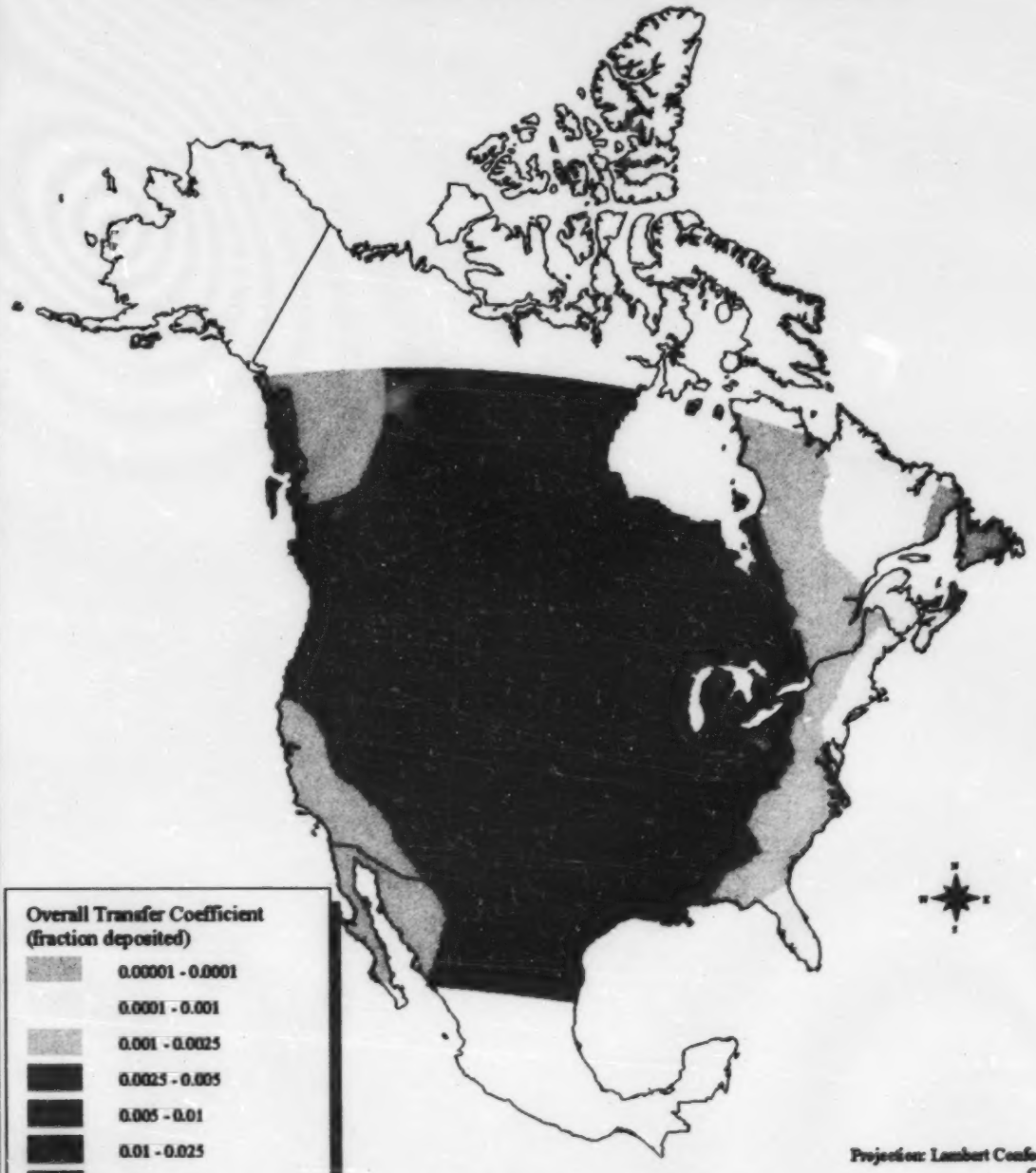

Overall Transfer Coefficient
(fraction deposited)
0.00001 - 0.0001
0.0001 - 0.001
0.001 - 0.0025
0.0025 - 0.005
0.005 - 0.01
0.01 - 0.025
0.025 - 0.05
0.05 - 0.1
outside of modding domain
300 0 300 600 Kilometers
300 0 300 600 Miles
Projection: Lambert Conformal Conic
These estimates- also called Transfer Coefficients- were developed using NOAA's HYSPLIT atmospheric fate and transport model.

FIGURE 10
Fraction of 1996 Dioxin Emissions Deposited in Lake Ontario
(grams TEQ deposited per year/grams TEQ emitted per year)

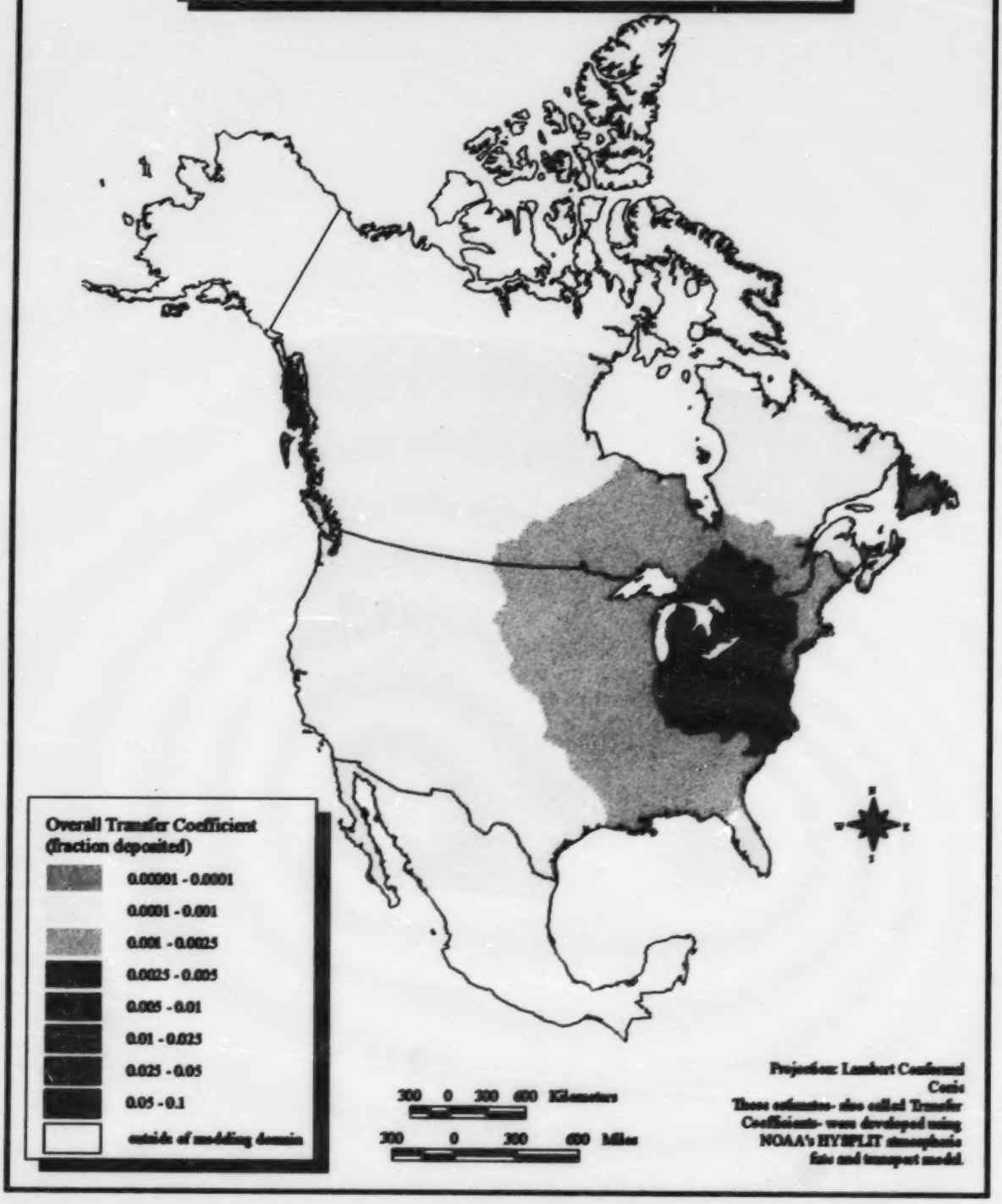

Overall Transfer Coefficient
(fraction deposited)
0.00001 - 0.0001
0.0001 - 0.001
0.001 - 0.0025
0.0025 - 0.005
0.005 - 0.01
0.01 - 0.025
0.025 - 0.05
0.05 - 0.1
outside of modeling domain
300 0 300 600 Kilometers
300 0 300 600 Miles
Projection: Lambert Conformal Conic
These estimates- also called Transfer Coefficients- were developed using NOAA's HYSPLIT atmospheric fate and transport model.

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FIGURE 11
Mid-Range Estimate of the Contribution to 1996 Atmospheric Deposition of Dioxin to Lake Superior (μgrams TEQ/km ^{2}-year)

FIGURE 12
Mid-Range Estimate of the Contribution to 1996 Atmospheric Deposition of Dioxin to Lake Superior
(percent contributed per year from each State and Province)

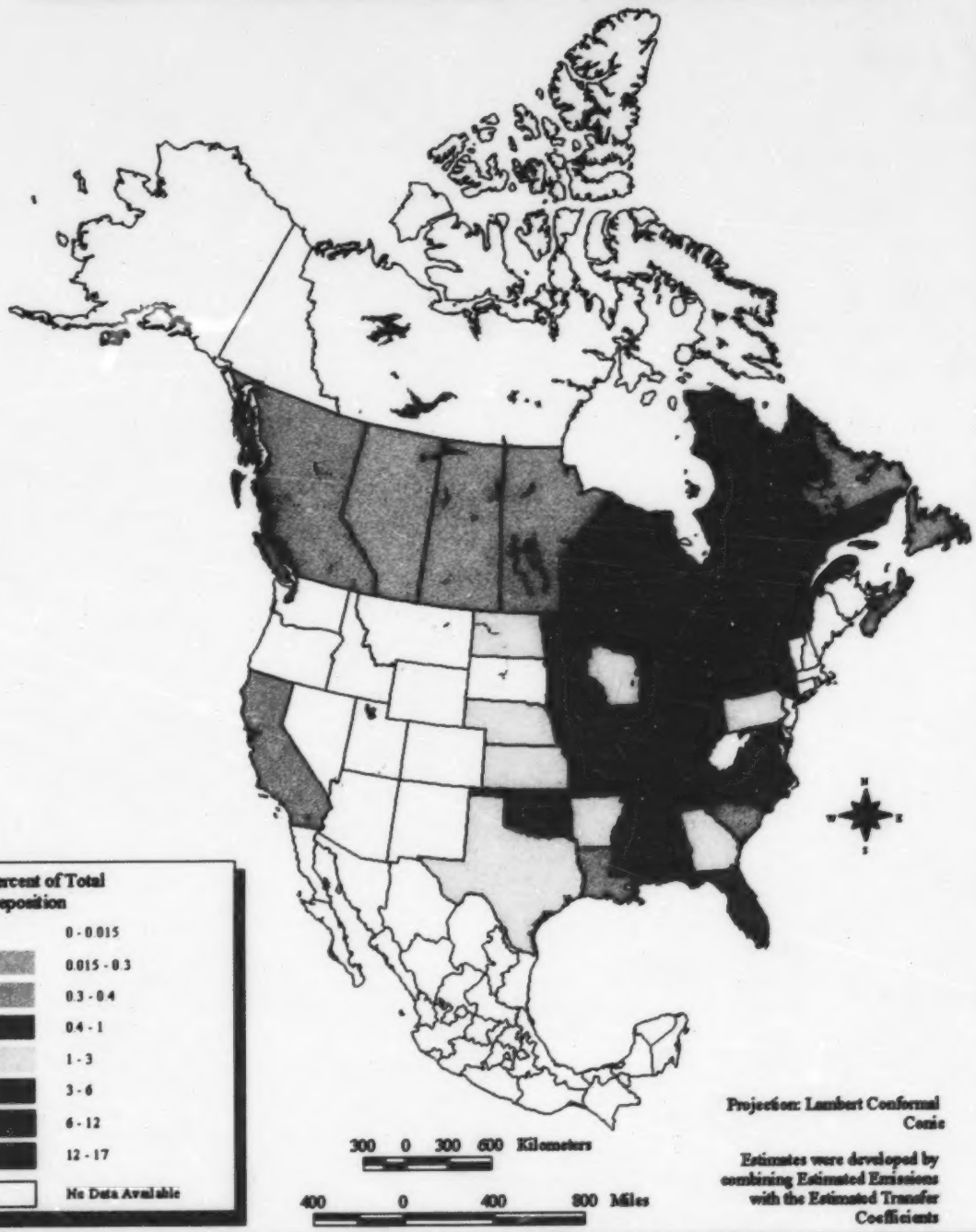

Percent of Total Deposition
0 - 0.015
0.015 - 0.3
0.3 - 0.4
0.4 - 1
1 - 3
3 - 6
6 - 12
12 - 17
No Data Available
300 0 300 600 Kilometers
400 0 400 800 Miles
Projection: Lambert Conformal Conic
Estimates were developed by combining Estimated Emissions with the Estimated Transfer Coefficients

FIGURE 13
Mid-Range Estimate of the Contribution to 1996 Atmospheric Deposition of Dioxin to Lake Ontario (μgrams TEQ/km ^{2}year)

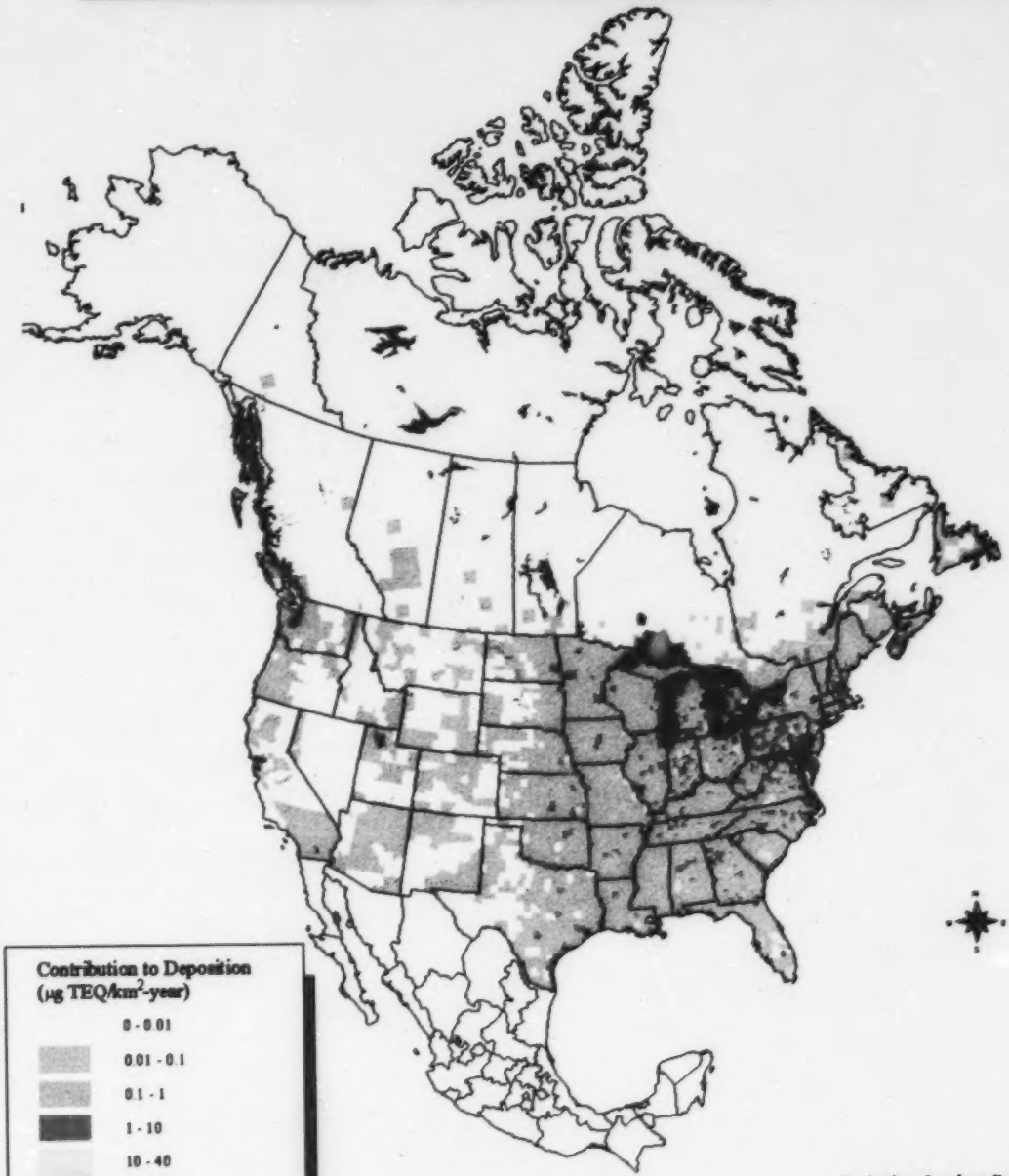


FIGURE 14
Mid-Range Estimate of the Contribution to 1996 Atmospheric Deposition of Dioxin to Lake Ontario
(percent contributed per year from each State and Province)

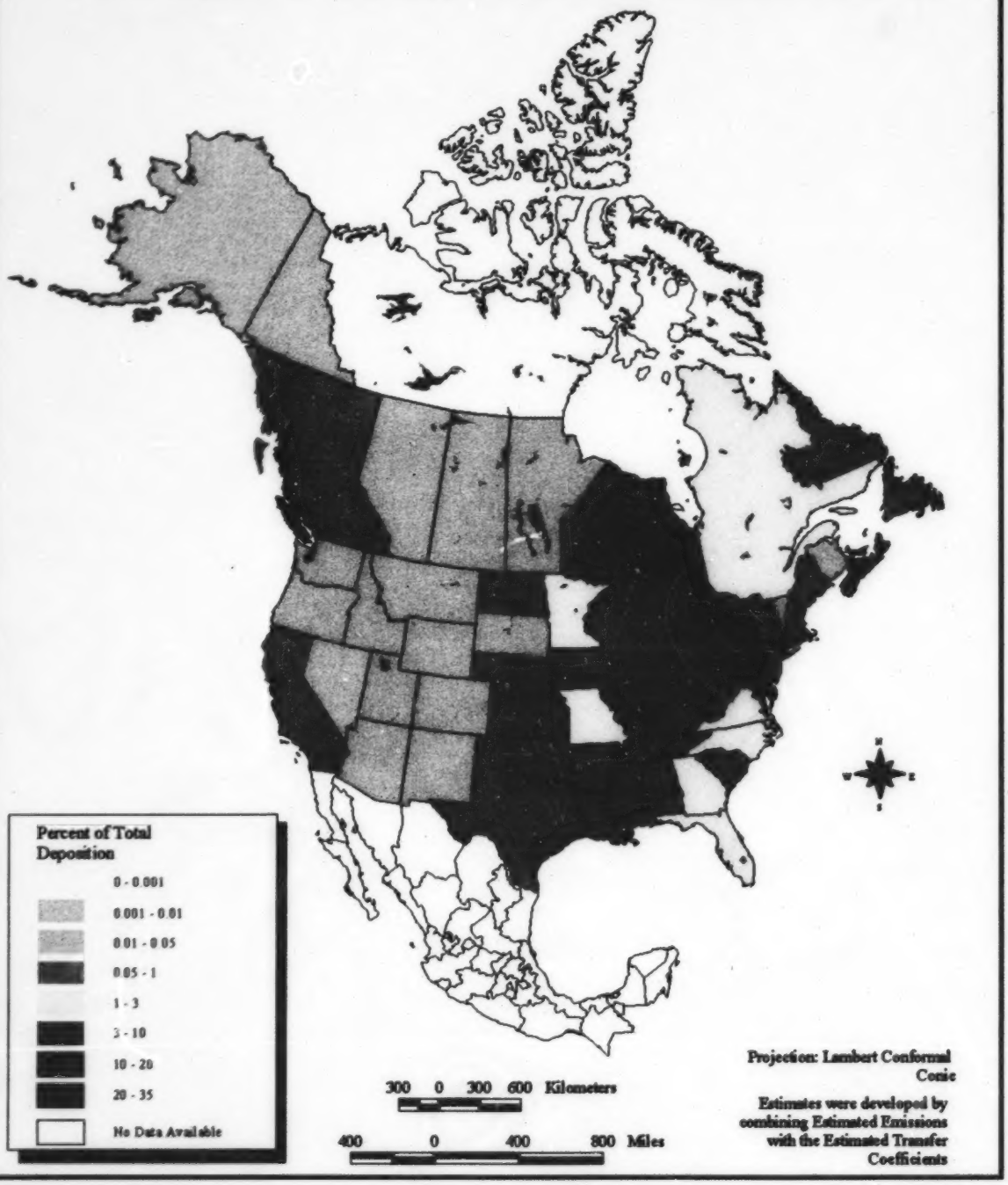

Percent of Total Deposition
0 - 0.001
0.001 - 0.01
0.01 - 0.05
0.05 - 1
1 - 3
3 - 10
10 - 20
20 - 35
No Data Available
300 0 300 600 Kilometers
400 0 400 800 Miles
Projection: Lambert Conformal Conic
Estimates were developed by combining Estimated Emissions with the Estimated Transfer Coefficients

Figure 15 Percent of Total Emissions or Deposition of Dioxin Arising from Different Distances from Each Great Lake

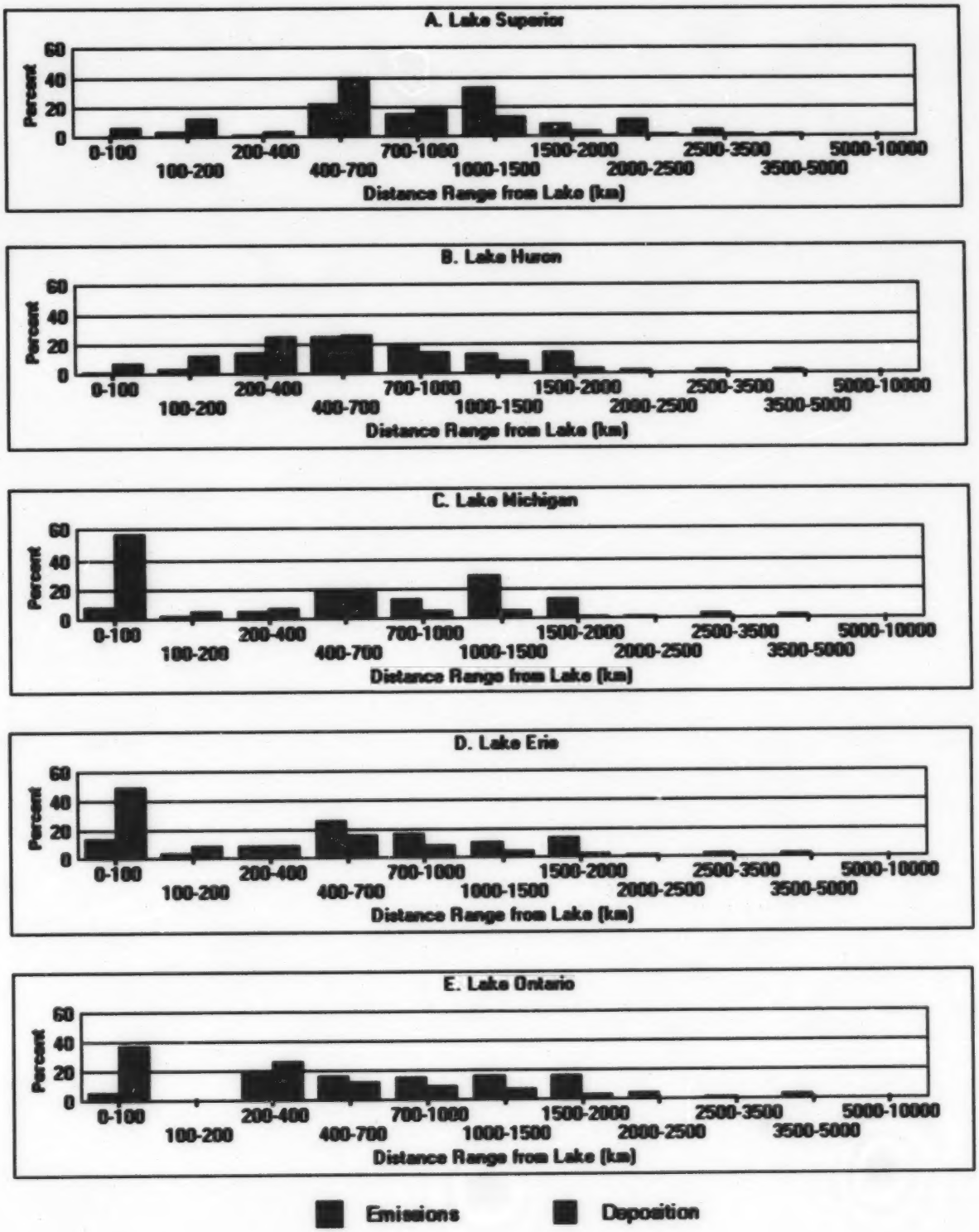


Figure 16
Percent of Total Emissions or Deposition of Dioxin Arising from States and Provinces in the Great Lakes Basin

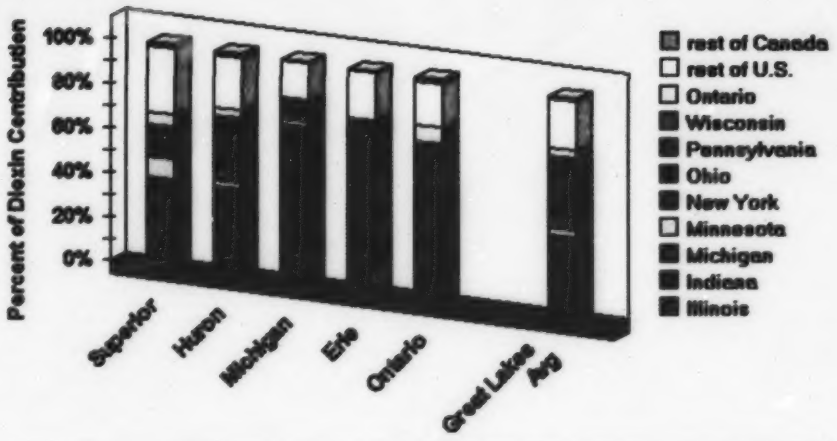
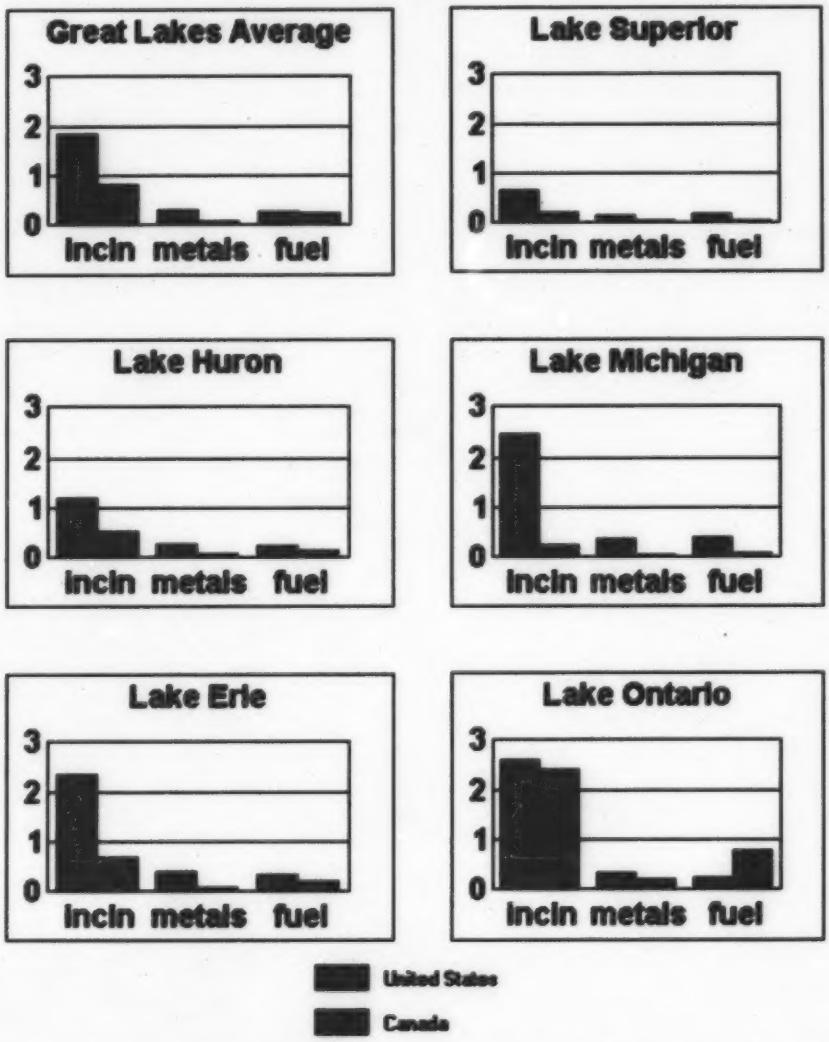


Figure 17
Contribution of Different Source Sectors to Atmospheric Deposition of Dioxin to the Great Lakes

(pg TEQ deposition/km²)/ (person - year)

(Each country's annual deposition flux contribution amount normalized by their total population).

For example, waste incineration in the U.S. is estimated to contribute 37.2 grams TEQ per year to Lake Michigan. Dividing by the area of the Lake (57,800 km²), this is equivalent to 0.000644 grams TEQ/ km²-year, or 6.44+8 pg TEQ/km²-year (a picogram is 1e-12 of a gram). Dividing by the population of the U.S. (265.2 million), one obtains the per-capita estimate of 2.43/km² per persion per year.



"incin" = waste incineration; "metals" = metallurgical processing; "fuel" = fuel combustion

Many uncertainties exist in emissions inventories for the U.S. and Canada, and the overall consistency between U.S. and Canada inventories is still being evaluated. For example, backyard burning of residential waste is not yet included for Canada.